Toward Operational Uses of Geostationary Imager Radiance Data in the GSI Analysis System

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Outline

- GOES of R3 Project
- Accomplishment thus far
- Accomplishment Anticipated at the end of Year 2
- Initial feedback from potential users (if any)
- What could be accomplished with the 3rd Year of Funding
- Summary and Conclusions

Goal of R3 Project

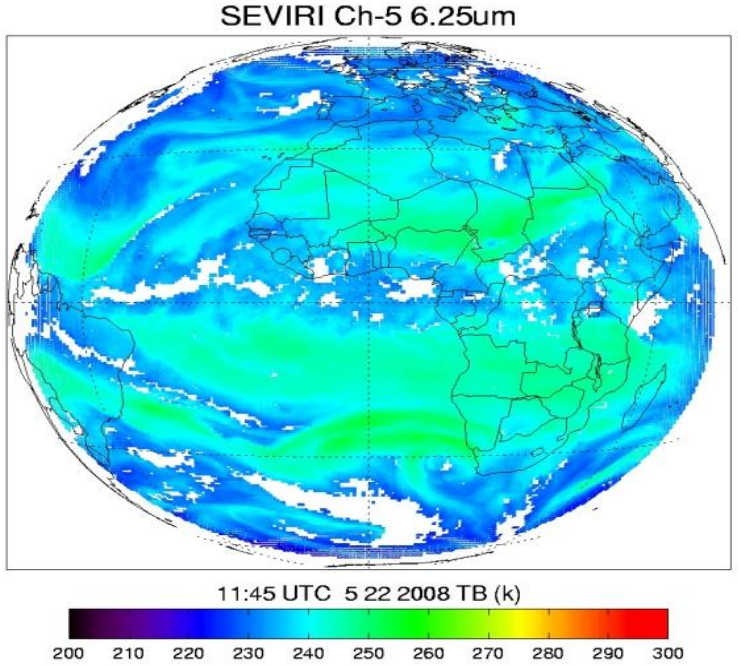
- Implementation of SEVIRI and GOES imager data in GFS
- Assimilation of SEVIRI and GOES data through uses of AWG LSE/LST products
- Uses of GOES and SEVIRI cloud-affected radiances in GFS
- Assimilation of high temporal resolution data from GOES and SEVIRI using advanced NCEP assimilation system

Project Milestones – Year 1

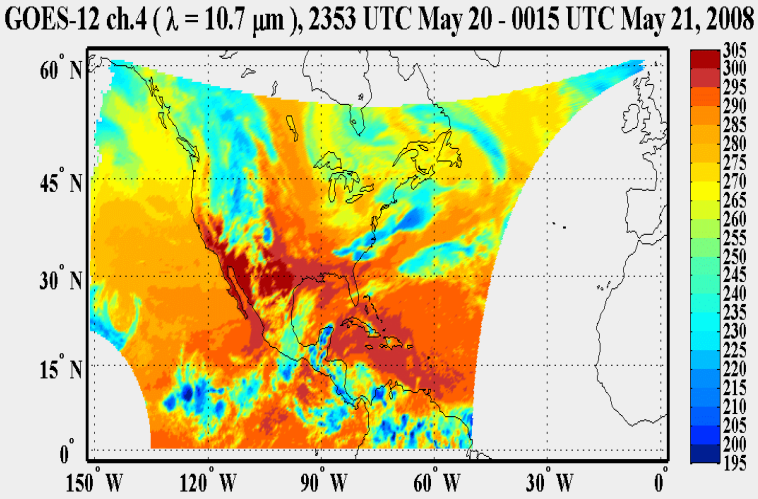
Tasks	Status
Complete studies of assimilation of SEVIRI and GOES imager data	Studied the impacts of SEVIRI and GOES imager data on GFS forecast (STAR/NCEP).
Continue the evaluation of infrared land surface emissivity databases in comparison with the current baseline CRTM emissivity	Compared two new and current CRTM IR emissivity models; and studied their impacts on CRTM simulations (STAR).
Investigate the GOES-R AWG and Met Office SEVIRI cloud algorithms for pixel level cloud detections and implement improved algorithm in GSI for the high resolution data	Evaluated the Met Office and EUMETSAT SEVIRI cloud mask algorithms (NCEP)
Suggest possible strategies to use efficiently all the SEVIRI or GOES data, given the possibility of limited resources at NCEP to use this data stream. This may include intelligent thinning or super-obbing	Evaluated the QC scheme for GOES/ SEVIRI CSR data assimilation, and updated QC for GOES Imager in GSI system (FSU/NCEP).
Convert the high resolution of MSG SEVIRI imager data into BUFR format	Generated two months ASR/CSR SEVIRI BUFR data, and one week GOES Imager high resolution BUFR data (STAR).

Prepared SEVIRI and GOES Imager High Resolution BURF Data for GDAS

SEVIRI CSR Ch-5 6.25 µm
11:45 UTC 05/22/ 2008



High resolution (4-km, 15-min) GOES-12 Imager



- Generated two months SEVIRI data and one week GOES Imager high resolution data in NCEP BUFR format for impact studies
- Transferred BUFR data convertor to NCEP/NCO, and the SEVIRI CSR data has been routinely generated for GSI assimilation

GSI Assimilation of SEVIRI and GOES Imager and Impacts of GSICS Correction

•Developed GSI modules and QC processes for assimilating SEVIRI CSR data

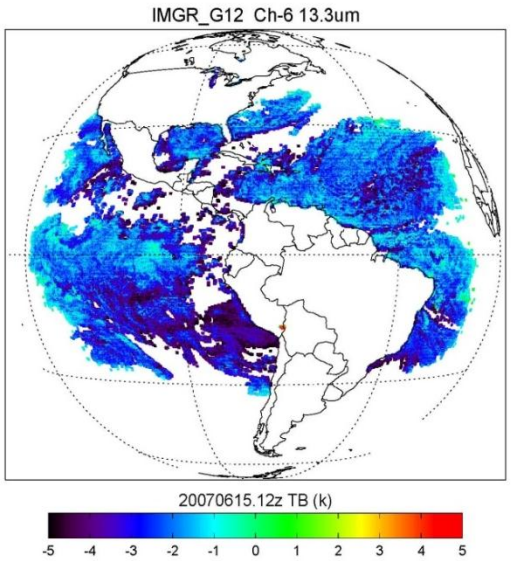
•Updated QC processes for assimilating GOES-11/12/13 Imager data in GSI

•Studied Impacts of GSICS Correction algorithms on SEVIRI and GOES Imager assimilation:

GSICS correction algorithm:

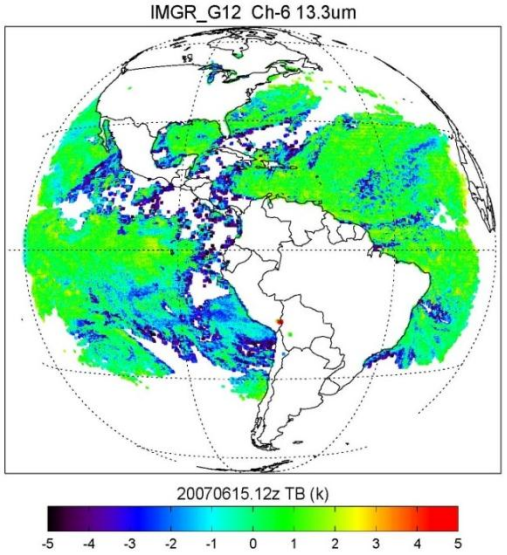
$$Rad_{new} = (Rad_{old} - b) / a$$

where ***a*** and ***b*** are GSICS coefficients.



GOES-12 Ch6(13.3 μm)

before GSICS correction O-B bias:-2.6K

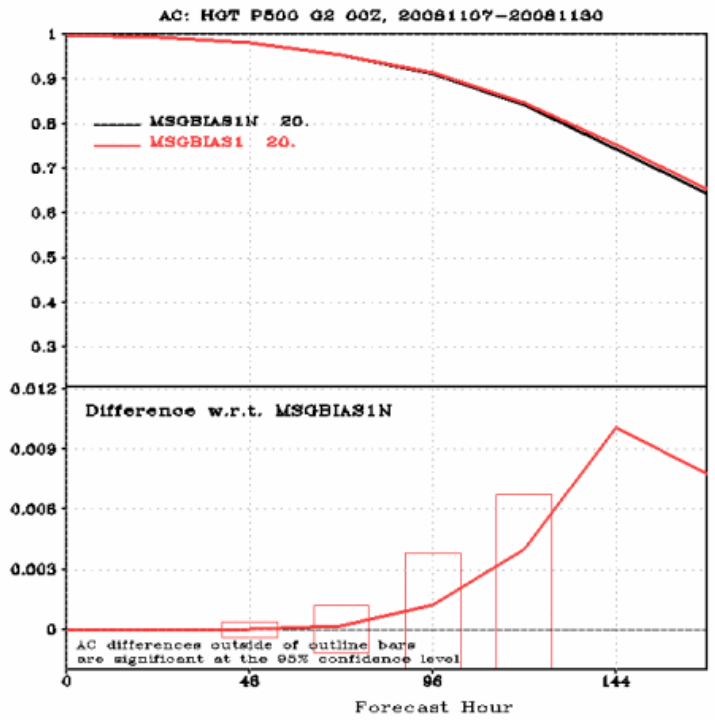


after GSICS correction O-B bias:-0.1K

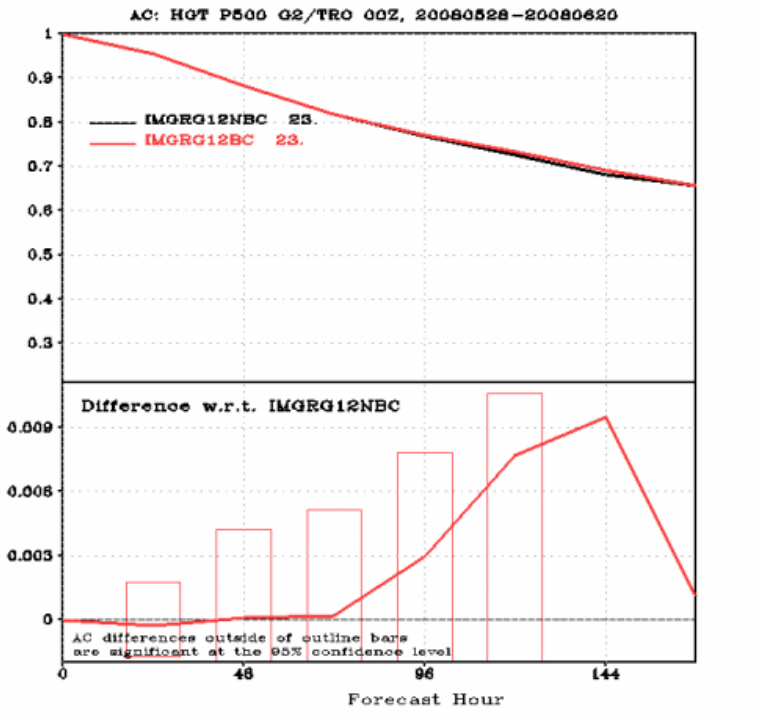
Impacts of GSICS Calibration Correction

Comparison of GFS forecasts with and without GSICS correction

SEVIRI CSR GSICS Correction AC for 500 hPa height



GOES-12 Imager GSICS Correction AC for 500 hPa height



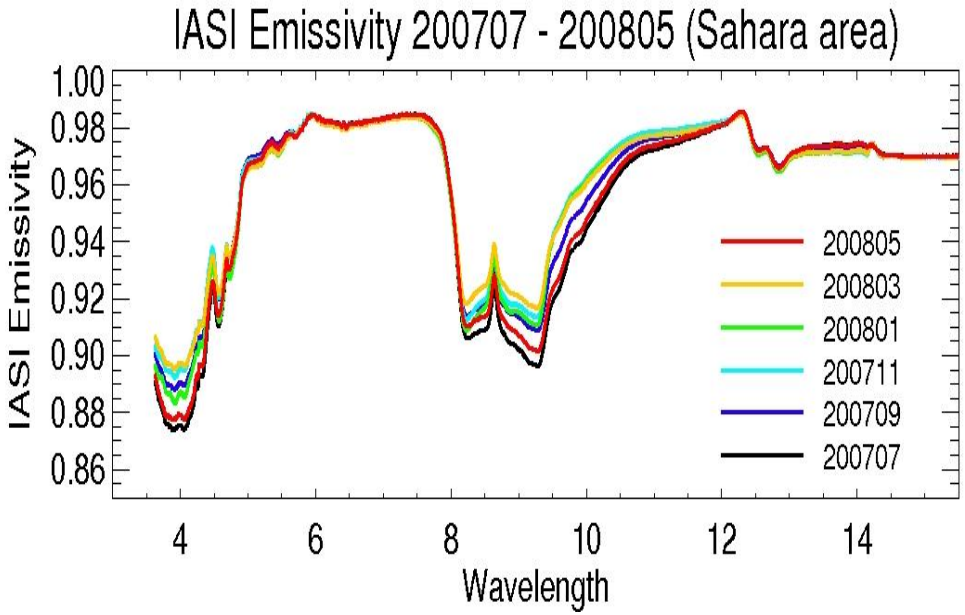
There is small positive impacts on GFS forecasts after performing GSICS correction for SEVIRI and GOES Imager data.

Two New IR Land Surface Emissivity Data Bases in CRTM

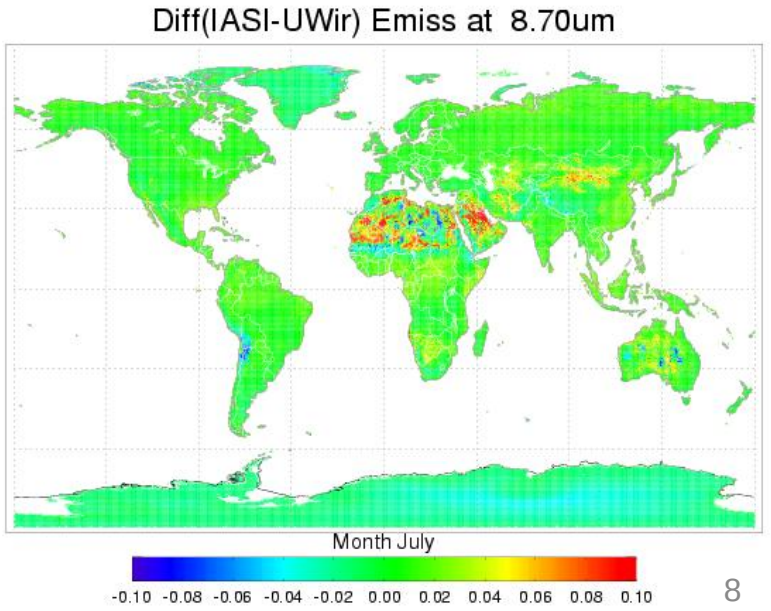
NASA/LARC IASI Emissivity
– by Dan Zhou et al.
•8461 IASI channels
•645 – 2760 (cm^{-1})
•0.5^0 x 0.5^0 lat/lon
•Monthly 07/2007 – 06/2008
•Combined, Daytime, Nighttime

UW-RTTOV IRemis module
-by Eva Borbas and Ben Ruston
•10 hinge points of UW/CIMSS BF global IR land
•Eigenfunction represents for the laboratory measurements
•From 3.6 to 14.3 µm
•0.1^0 x 0.1^0 lat/lon .

LARC IASI Emissivity Monthly Variation Averaged over Sahara Desert Region



Difference of IASI and UWIR Emissivity in July



Project Milestones – Year 2

Tasks	Status
Begin tests of using IR cloudy radiances with hybrid cloud information	Working on GOES-R AWG, Met Office and EUMETSAT SEVIRI cloud detection algorithms; and implementing in GSI system (FSU/NCEP)
Begin assimilation tests on preferred IR emissivity databases	Testing the impacts of the two new IR emissivity databases on GFS forecast for spring and winter seasons (STAR).
Develop strategy to use high resolution operational GOES, MSG and GOES-R imager data in GSI analysis system	Studying GOES Imager data impacts on high resolution WRF model simulations with new GSI assimilation strategy (FSU).
Incorporate the new GSICS inter-sensor calibration algorithms for new GOES and MSG imagers into GSI system	Completed in year 1 (STAR)

GOES Imager Impact on High Resolution Mesoscale Model

Advanced Research WRF (ARW) Model

Forecast Period: 0000-2400 UTC May 23, 2008

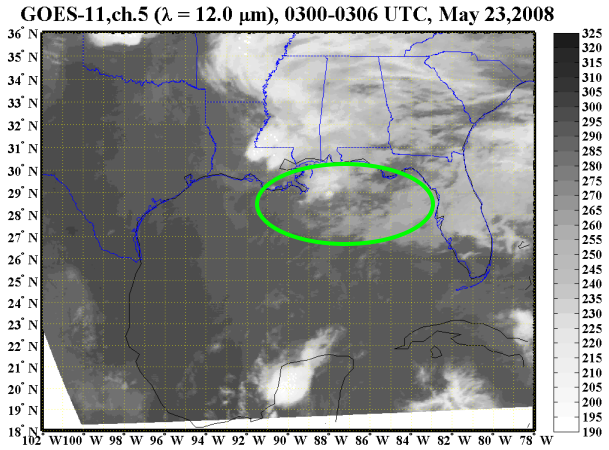
Resolution:	10 km, 27 layers
Domain size:	250x200x27
Microphysics:	WRF single-moment 3-class scheme
PBL:	Yonsei University scheme
Cumulus:	Kain-Fritsch scheme
Radiation:	Dudhia scheme

Zou, X., Qin. Z., F. Weng, 2011: Improved Coastal Precipitation Forecasts with Direct Assimilation of GOES 11/12 Imager Radiances, Mon. Wea. Rev.

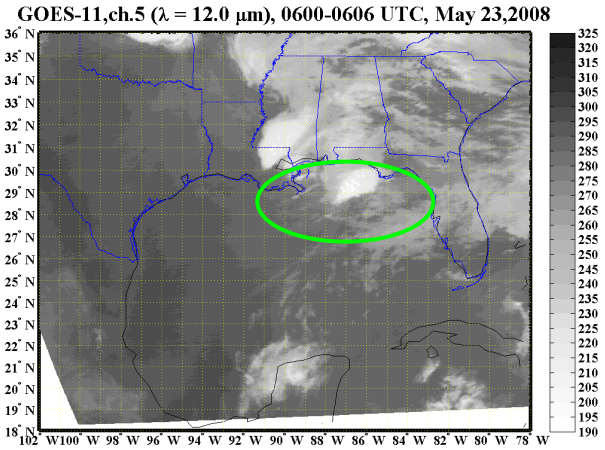
Satellite	Instruments	Satellite	Instruments	Satellite	Instruments
NOAA-14	[HIRS/2][(1)]	**MetOp-A**	**HIRS/4**	**GOES-11**	(SNDR)
	[MSU]		**AMSU-A**		**Imager**
NOAA-15	**AMSU-A**		**MHS**		**SNDRD1**
	AMSU-B		[IASI]		**SNDRD2**
NOAA-16	(HIRS/3) [(2)]	**Aqua**	**AIRS**		**SNDRD3**
	(AMSU-A)		(AMSU-A)		**SNDRD4**
	AMSU-B		(AMSRE)	**GOES-12**	(SNDR)
	(AVHRR3)	**F13**	(SSMI)		**Imager**
NOAA-17	**HIRS/3**	**F14**	(SSMI)		**SNDRD1**
	(AMSU-A)	**F15**	(SSMI)		**SNDRD2**
	AMSU-B	**F16**	(SSMIS)		**SNDRD3**
	(AVHRR3)				**SNDRD4**
NOAA-18	(HIRS/4)			**GOES-13**	(SNDR)
	AMSU-A				(Imager)
	MHS				(SNDRD1)
	(AVHRR3)				(SNDRD2)
***Satellite data assimilated with GSI in this study**					(SNDRD3)
(1)Data not available for this case.					(SNDRD4)
(2)Instruments removed from operational data assimilation.					

Observed BT of GOES-11 Ch5 on May 23, 2008

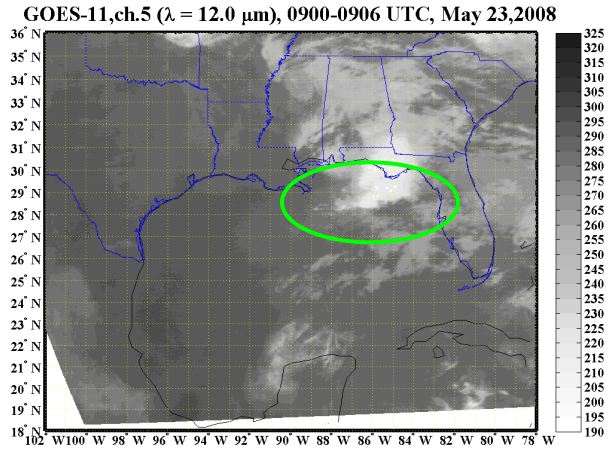
0300-0306 UTC



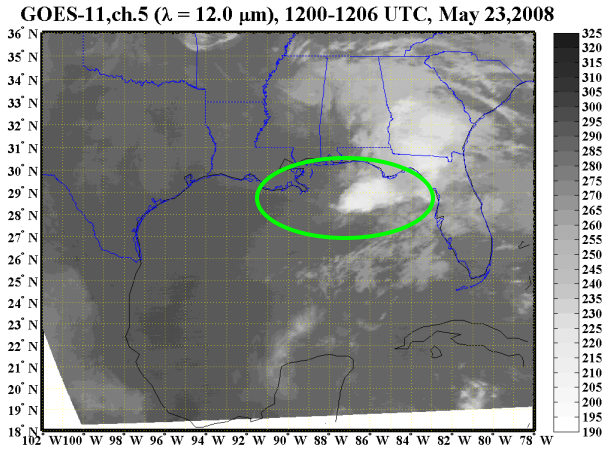
0600-0606 UTC



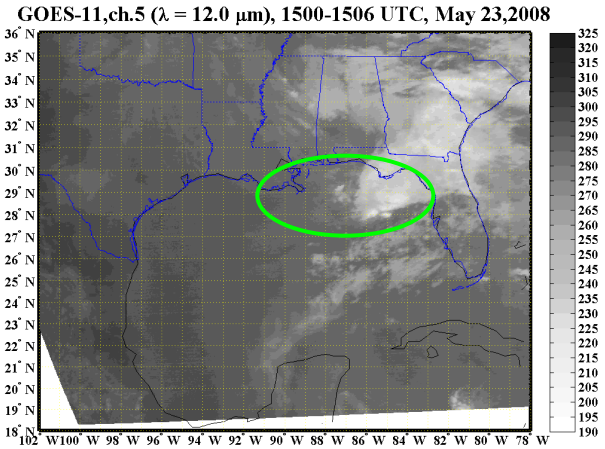
0900-0906 UTC



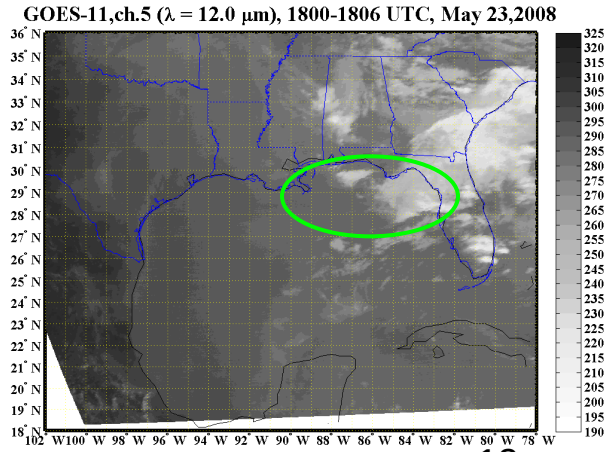
1200-1206 UTC

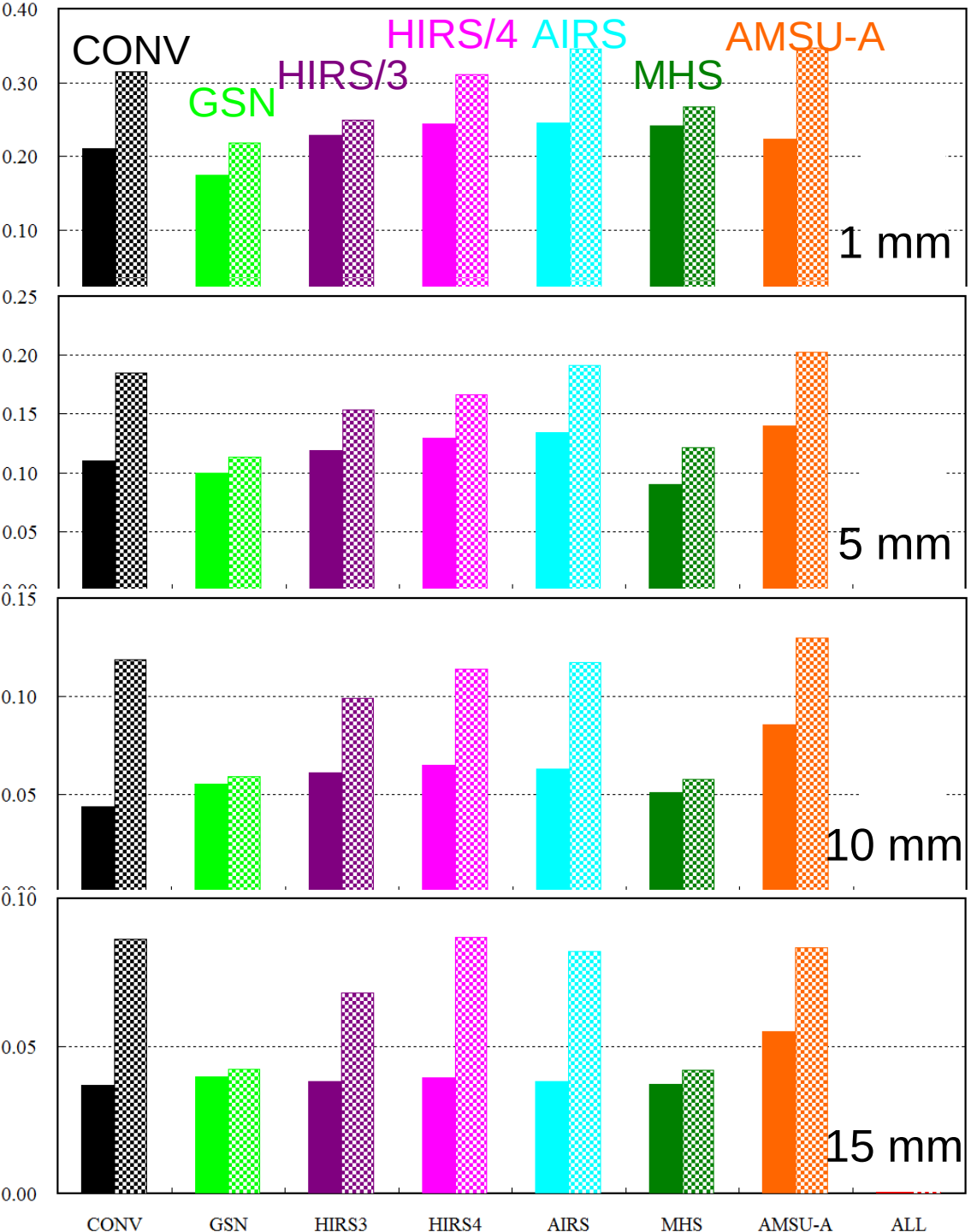


1500-1506 UTC



1800-1806 UTC



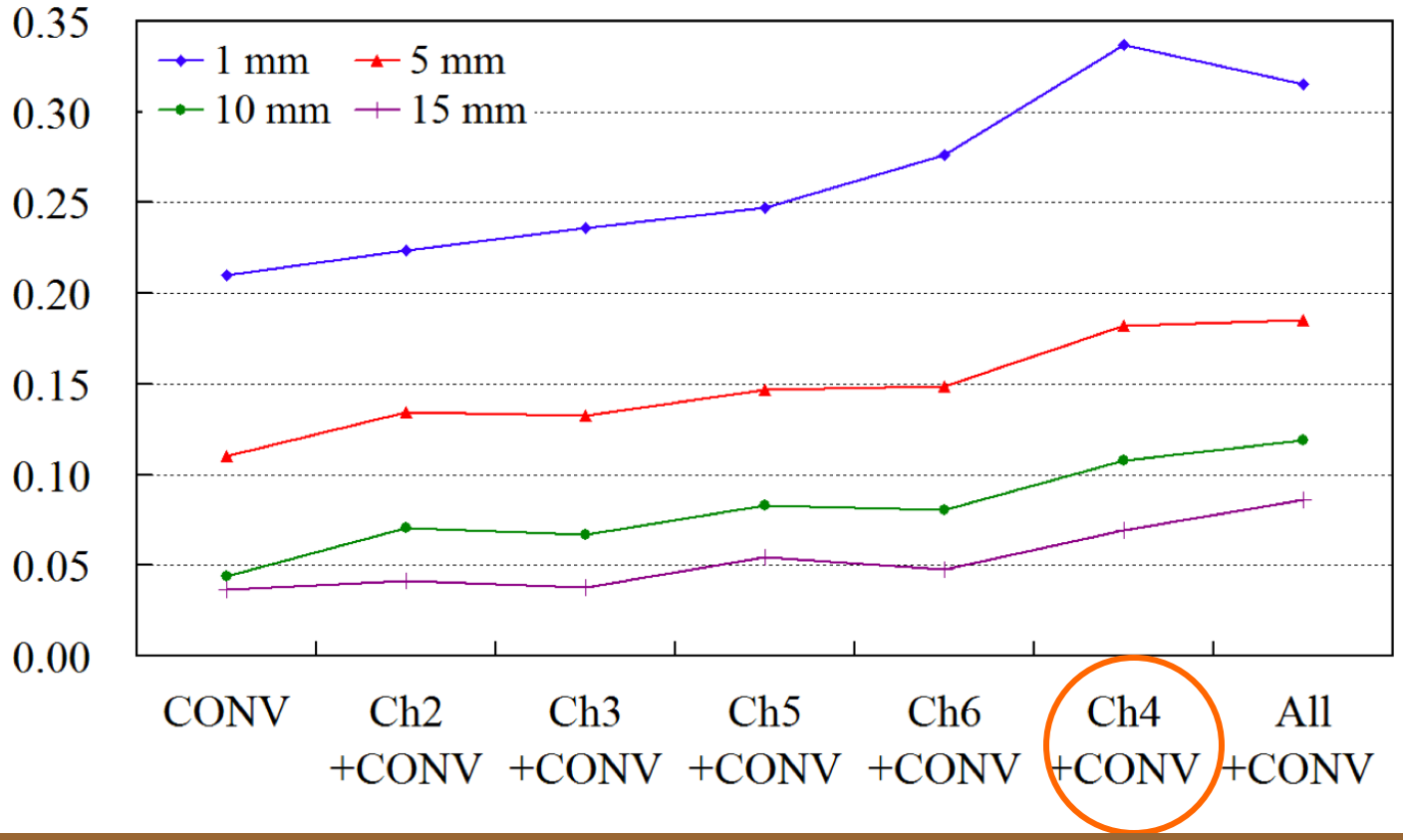


Threat scores of
3-h accumulative rainfall
averaged over 24 hours

Without GOES Imager (left bar)
With GOES Imager (right bar)

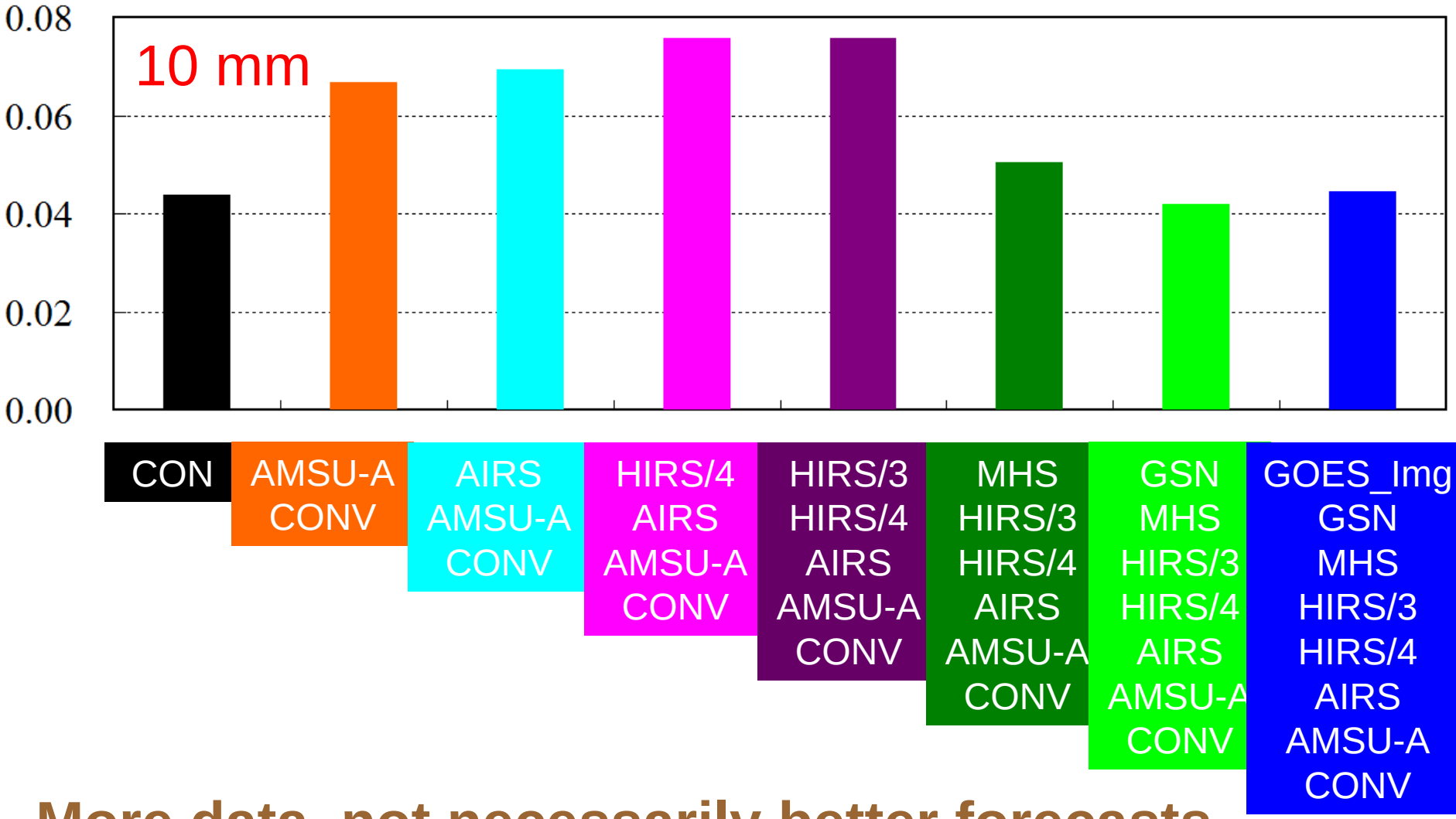
Uses of GOES Imager radiances improves the assimilation of any single sensor data

GOES Imager Single-Channel Experiments



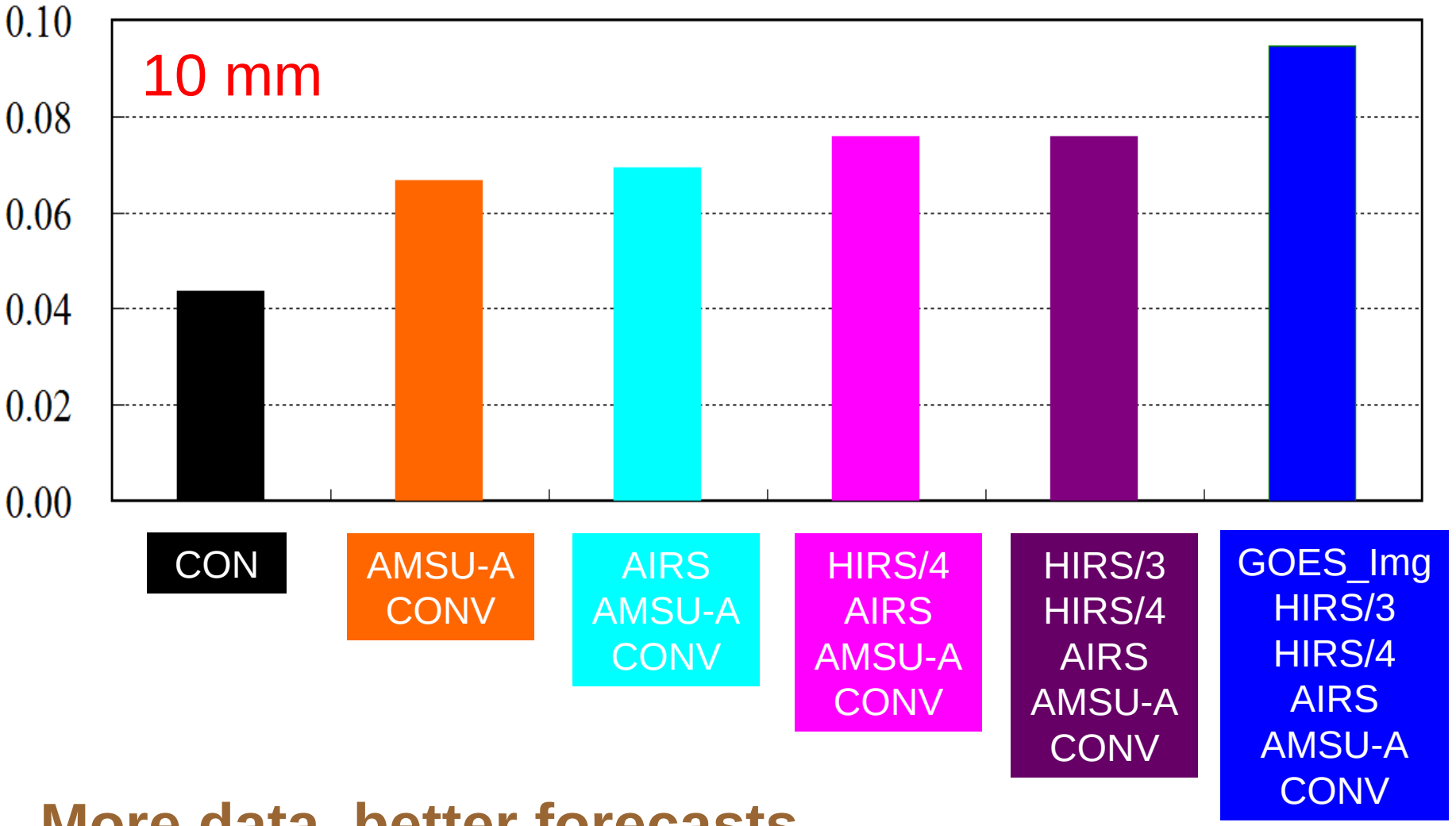
- Not only for small precipitation, for heavy rainfall, threat scores give the same result, and for heavy rainfall, the advantage of GOES Imager is more obvious.
- Among GOES Imager channels, Ch-4 gives the most contribution to rainfall forecast skill.

Threat Scores of 3-h Accumulative Rainfall



More data, not necessarily better forecasts.

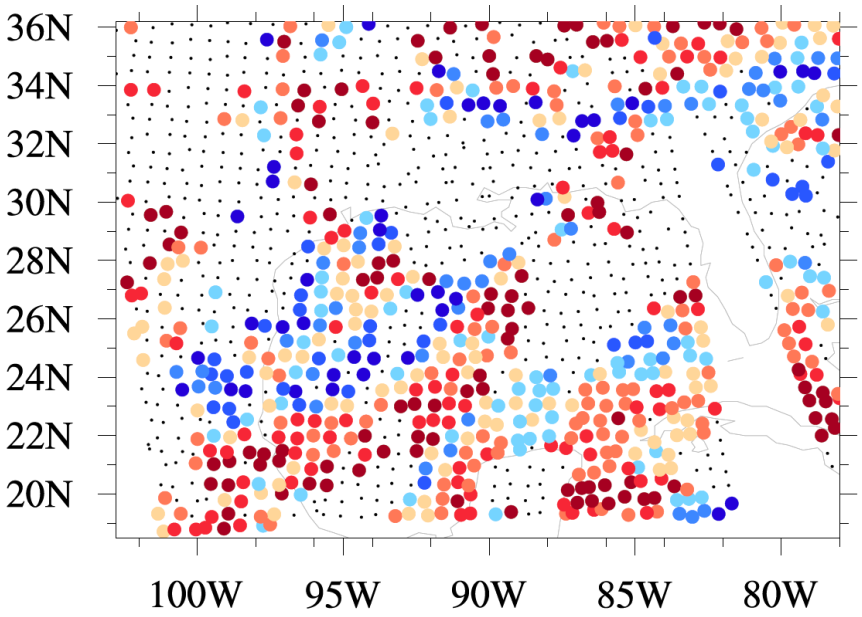
Threat Scores of 3-h Accumulative Rainfall



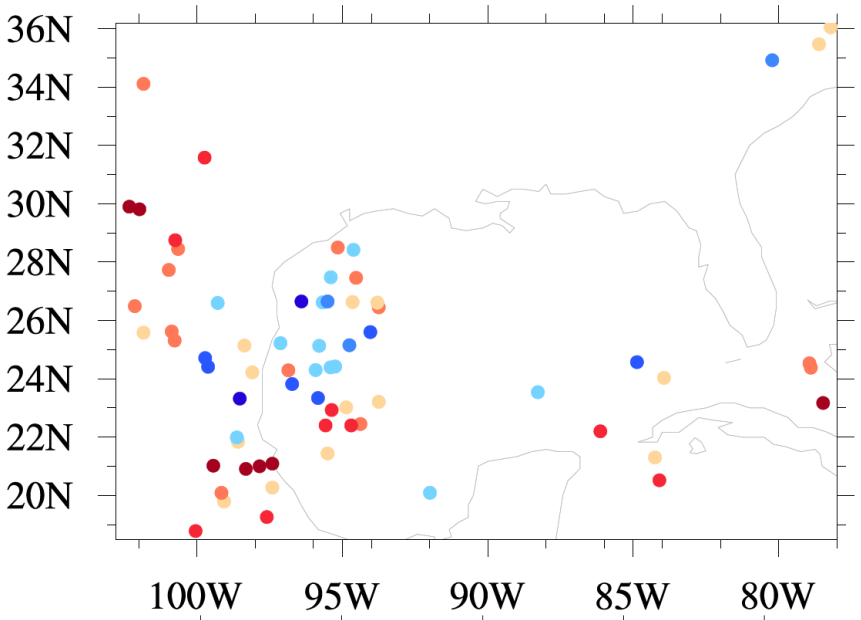
More data, better forecasts.

O-B (MHS Channel 3 at 1800 UTC 05/22/08)

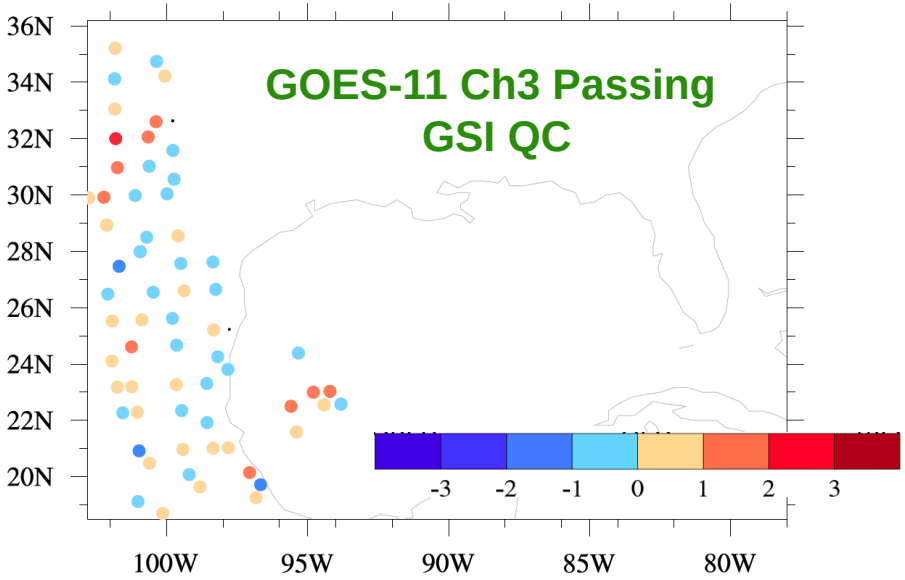
MHS Passing GSI QC



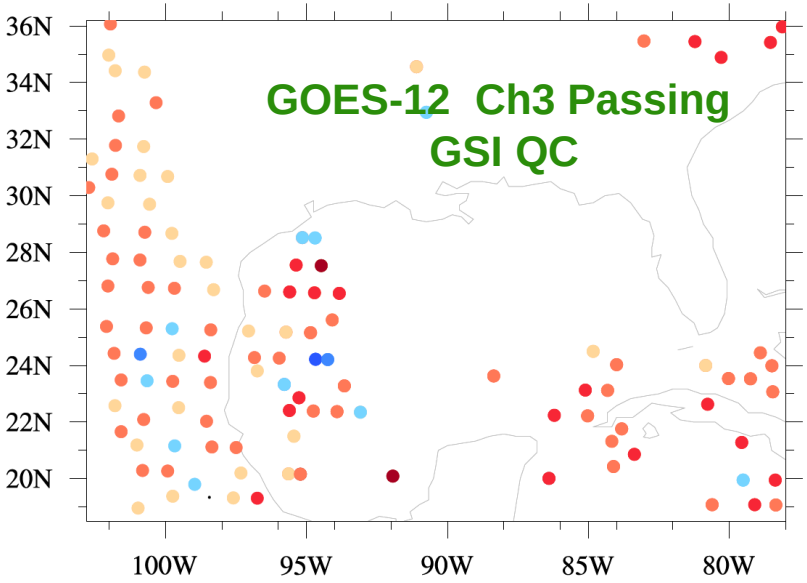
A Subset of MHS in Clear Sky



GOES-11 Ch3 Passing GSI QC

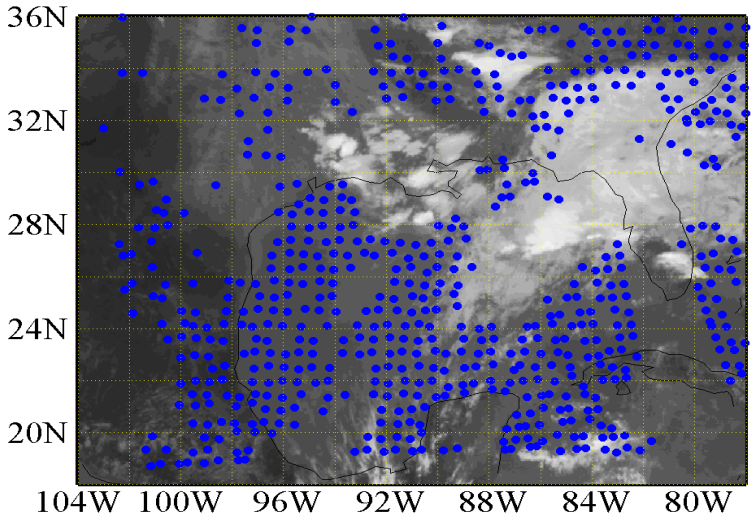


GOES-12 Ch3 Passing GSI QC

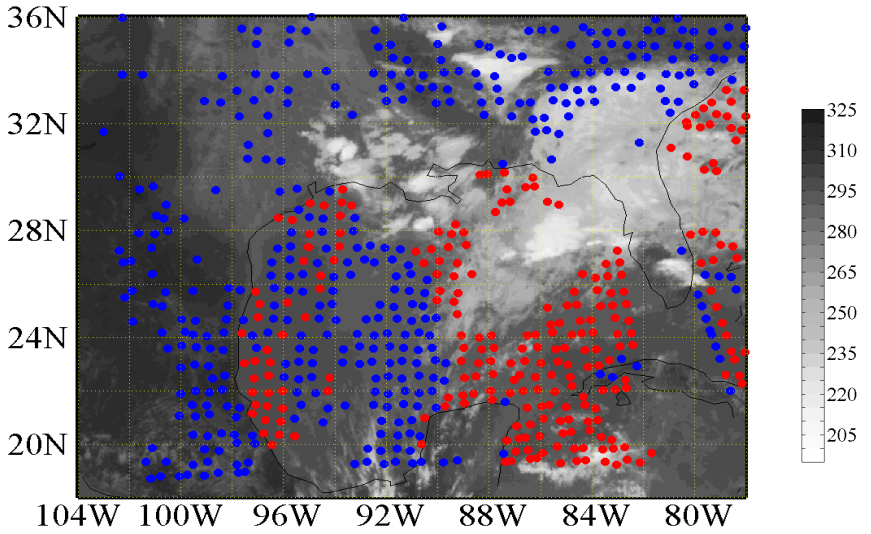


O-B (MHS Channel 3 at 1800 UTC 05/22/08)

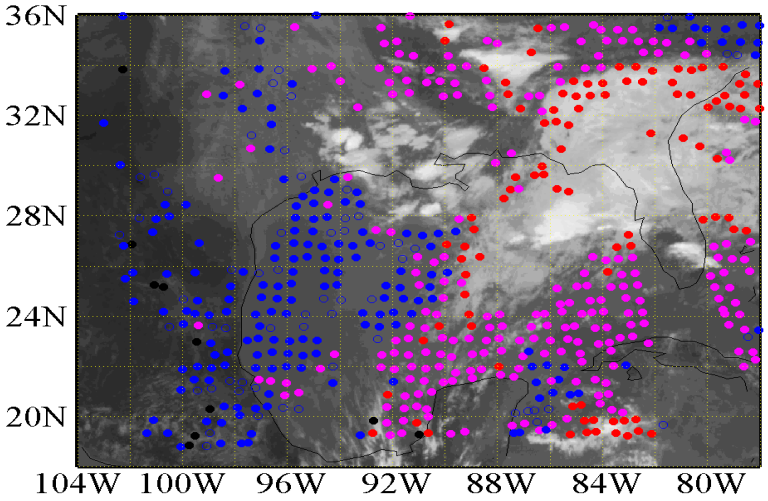
MHS Ch 3 Passing GSI QC



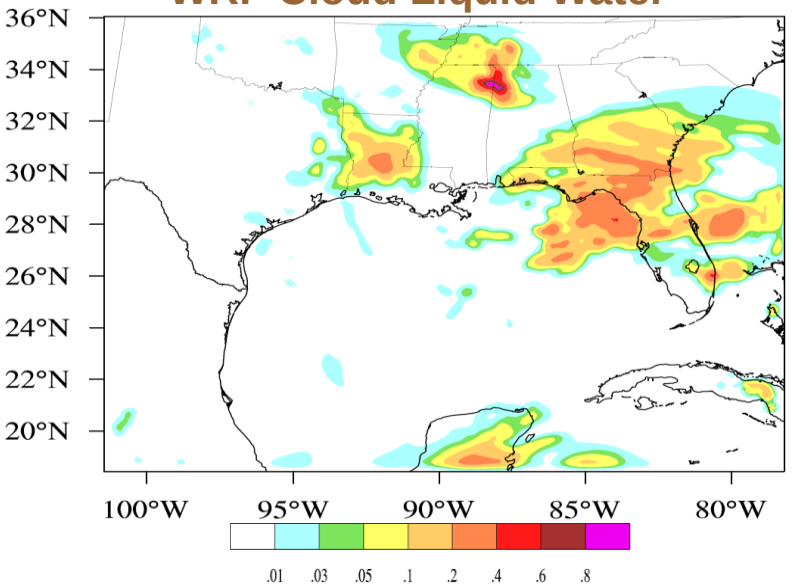
MHS Ch3 Affected by Clouds over Oceans

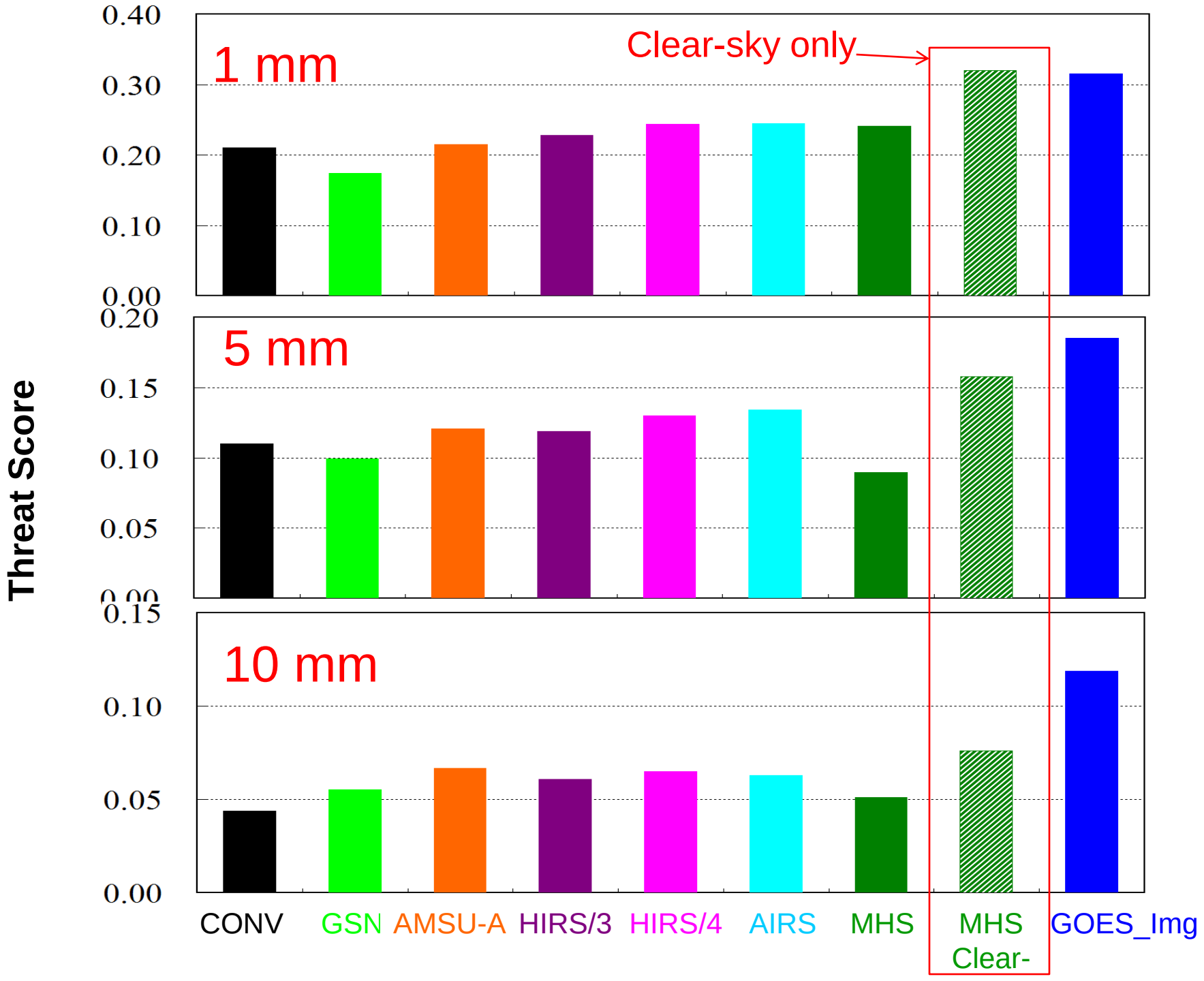


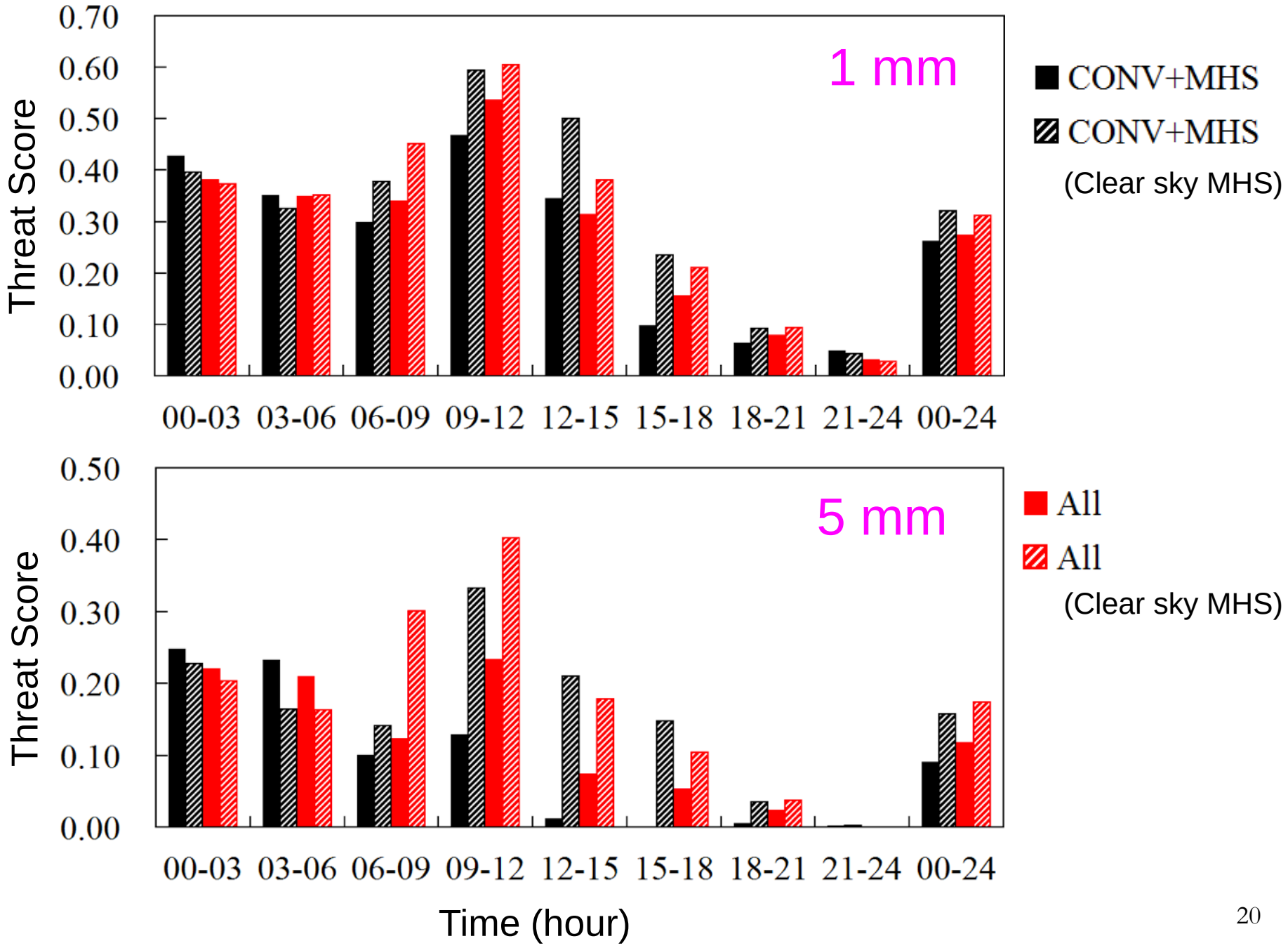
MHS Ch3 Removed by New Cloud Algorithms



WRF Cloud Liquid Water




Threat Score
1 mm
5 mm
10 mm
Clear-sky only
0.40
0.30
0.20
0.10
0.00
0.20
0.15
0.10
0.05
0.00
0.15
0.10
0.05
0.00
CONV
GSN
AMSU-A
HIRS/3
HIRS/4
AIRS
MHS
MHS
Clear-
GOES_Img


1 mm
Threat Score
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
00-03
03-06
06-09
09-12
12-15
15-18
18-21
21-24
00-24
CONV+MHS
CONV+MHS
(Clear sky MHS)
5 mm
Threat Score
0.50
0.40
0.30
0.20
0.10
0.00
00-03
03-06
06-09
09-12
12-15
15-18
18-21
21-24
00-24
All
All
(Clear sky MHS)
Time (hour)

Study of Cloud Detection Algorithm in GSI

Cloud Detection Algorithms:

- GOES-R AWG Cloud Mask
- UKMet office SEVIRI Cloud Mask
- EUMETSAT SEVIRI Cloud Mask

Data:

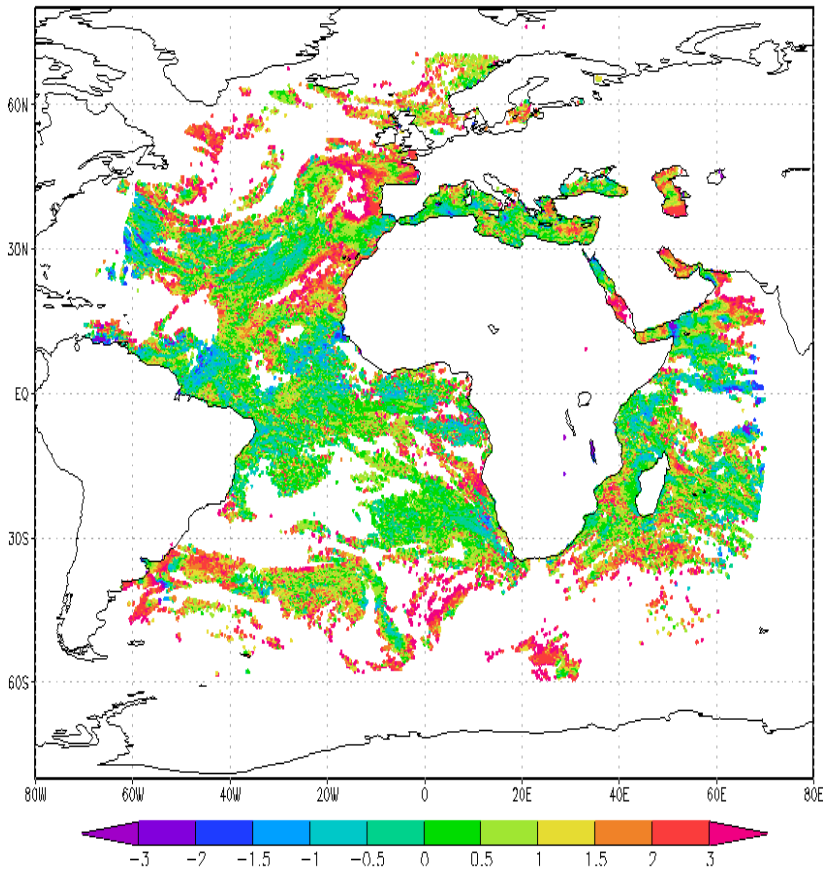
- SEVERI Lev1.5 data as a proxy of GOES-R ABI data
- NCEP GFS forecast

Models:

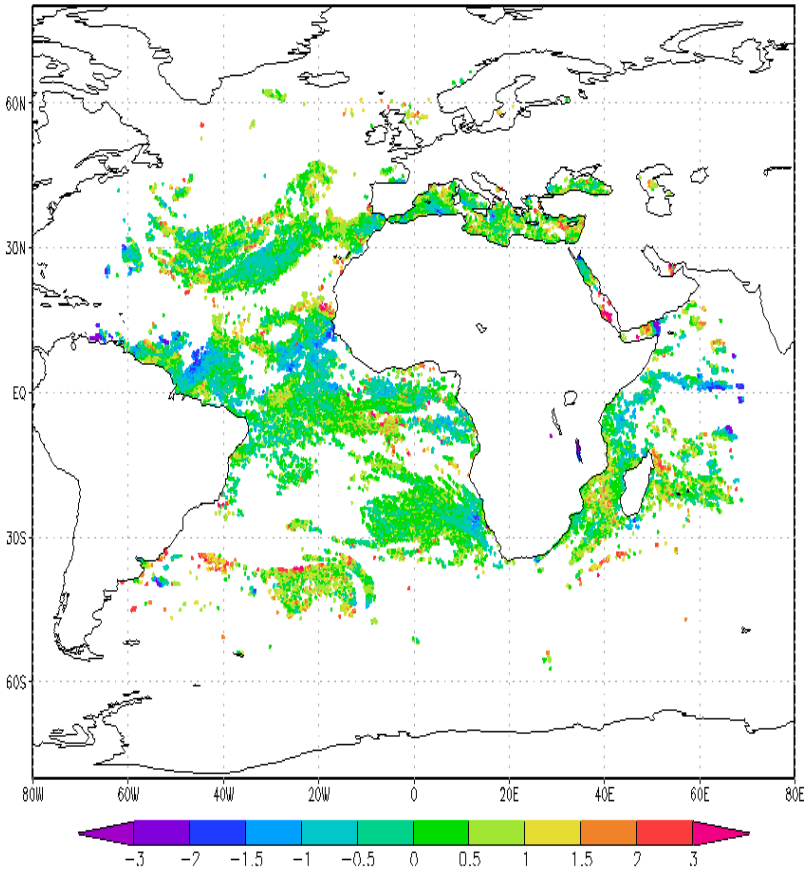
- JCSDA Community Radiative Transfer Model (CRTM)
- NCEP Gridpoint Statistical Interpolation (GSI)

MSG SEVIRI Data Used in NCEP/GFS

(B-O) using EUMETSAT Cloud Mask

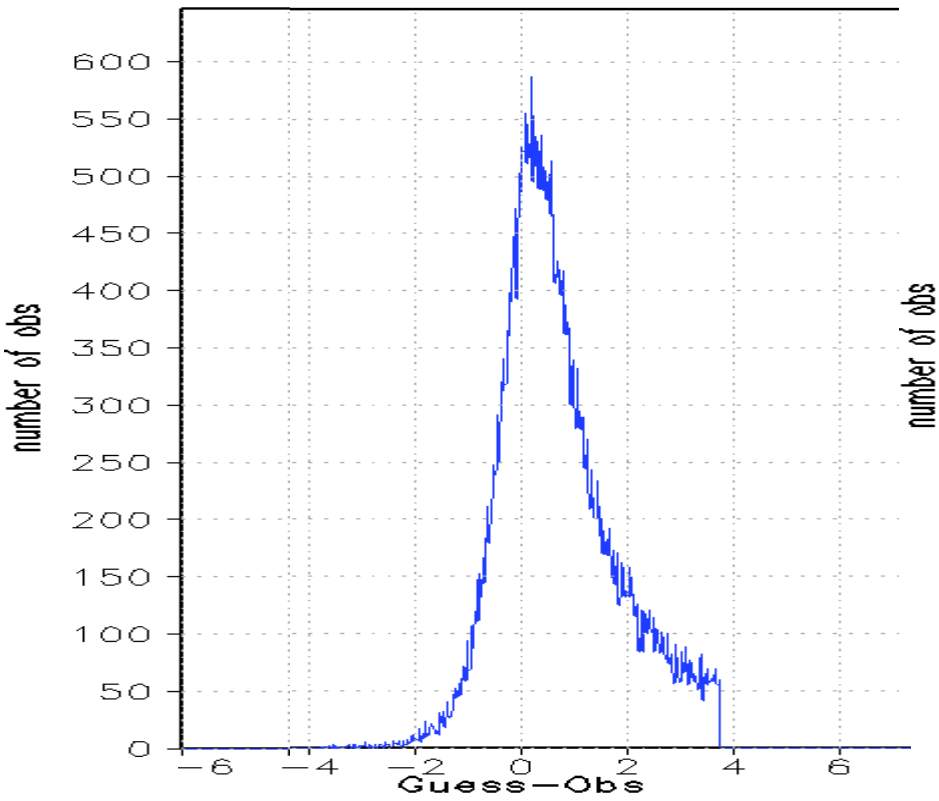


(B-O) Using AWG Cloud Algorithm

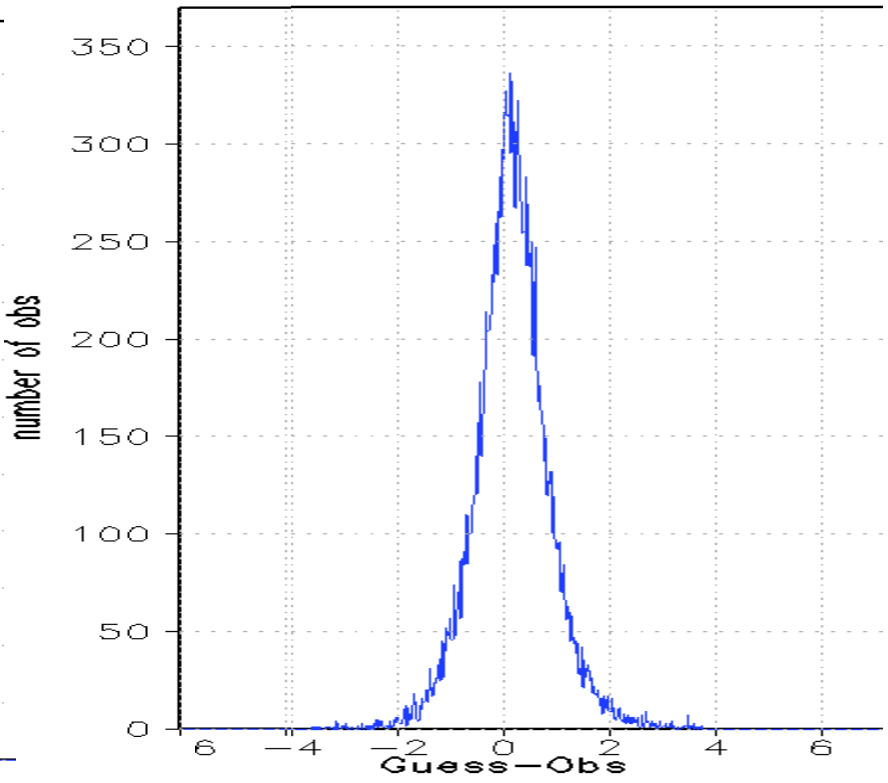


B-O Histogram for SEVIRI Ch-11

Using EUMETSAT CM



Using AWG CM



GSI B-O biases indicate most cloud pixels are removed for daytime case

Initial Feedback from Potential Users

- NCEP/EMC is funded through the project and is a strong team player. Specifically,
  - SEVIRI CSR data has been converted into NCEP BUFR format, and is operationally produced for GSI by NCEP/NCO
  - Developed and updated GSI modules and QC processes for assimilating SEVIRI and GOES Imager data

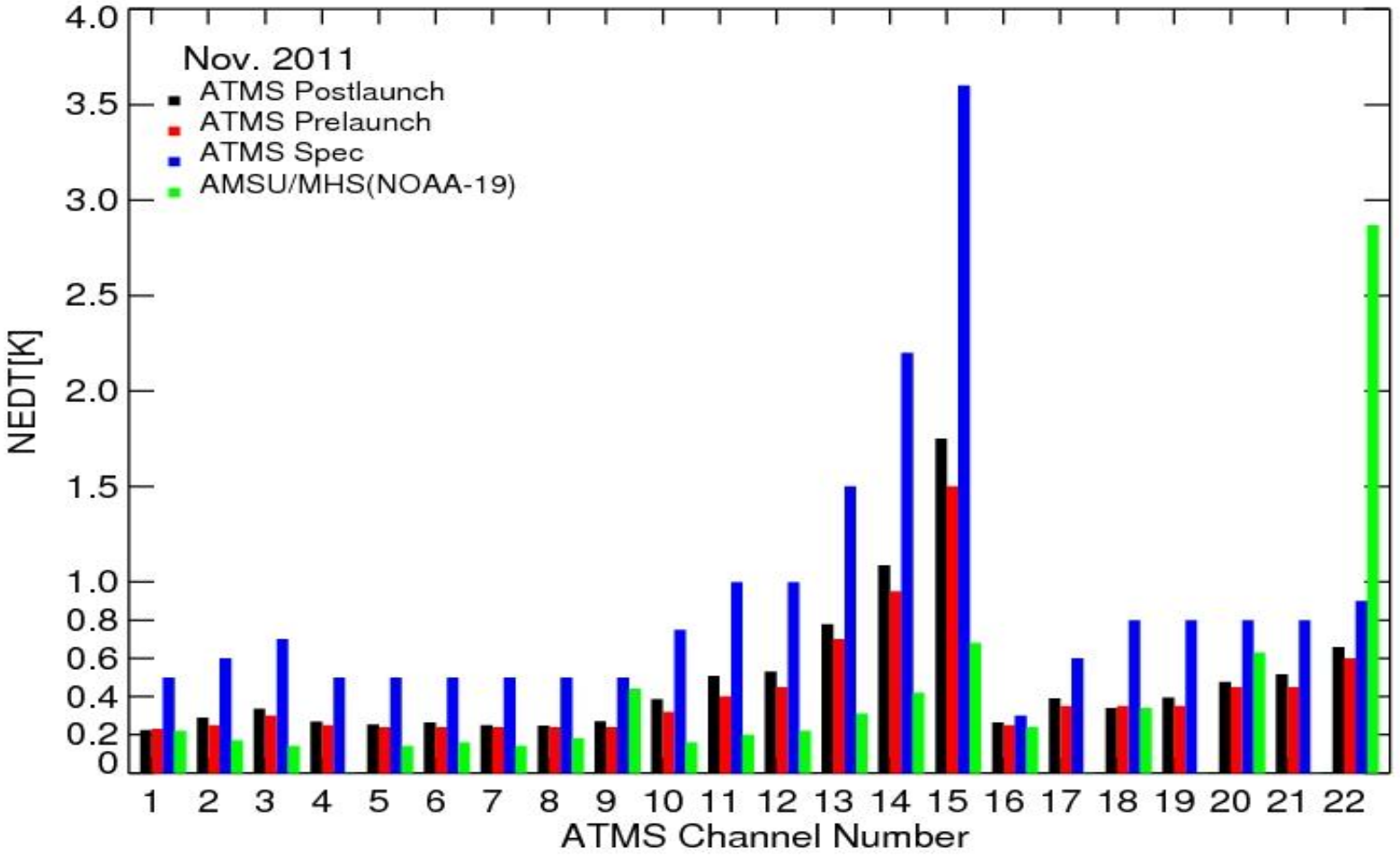
- Work closely with JCSDA CRTM team
  - Developed interface for CRTM to utilize IR land surface emissivity database
  - CRTM 2.1 is now executed 15 times faster than the early version for both AWG and data assimilation. The root-cause for the slow computation in the current version is caused by continual initialization of scattering coefficients under clear condition.

- GSI quality controls for other satellite data are improved and the results benefit to the assimilation of both JPSS and GOES-R programs

Project Milestones – Year 3

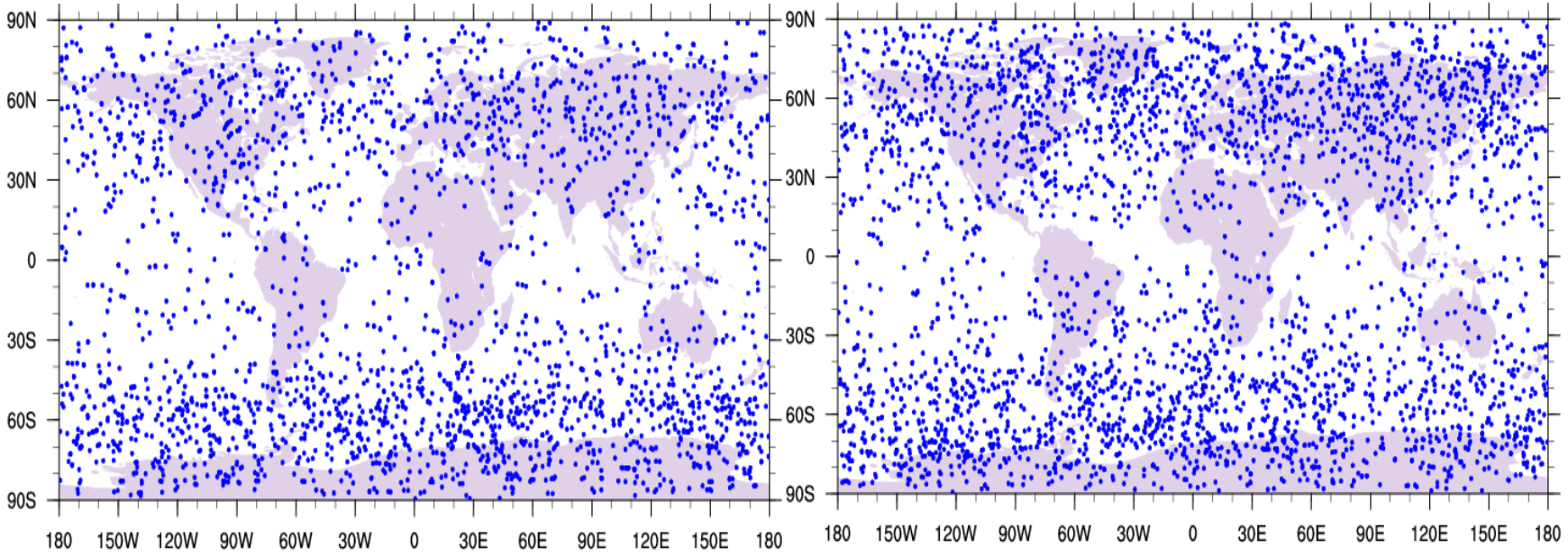
Tasks	Status
Complete SEVIRI data assimilation with the new emissivity model	In progress
Complete testing of use of IR cloudy radiances	In planning
Complete system to use high resolution data and test on operational GOES imager data	High res goes data is bufred
Ensure all positive developments are incorporated in the NCEP test and evaluation system.	On track, also plan to expand uses of NPP/JPSS data in HWRF

ATMS Noise Equivalent Differential Temperature (NEDT)



ATMS Calibration Accuracy Derived Using GPSRO Data and LBLRTM

Distance<30km Time difference<30min



Dec.10~31, 2011
(2649)

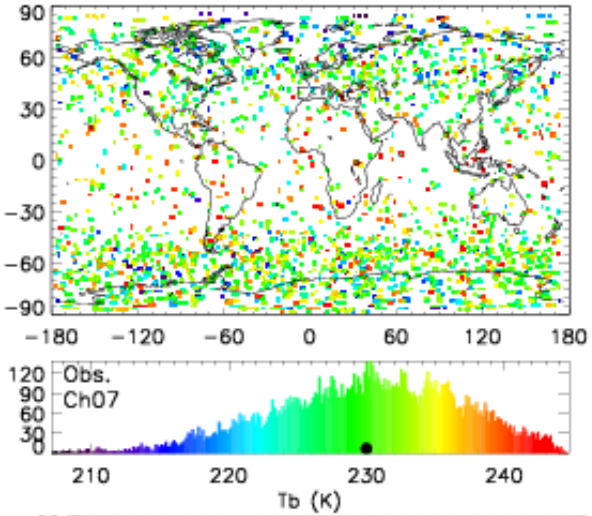
Jan. 2012
(3058)

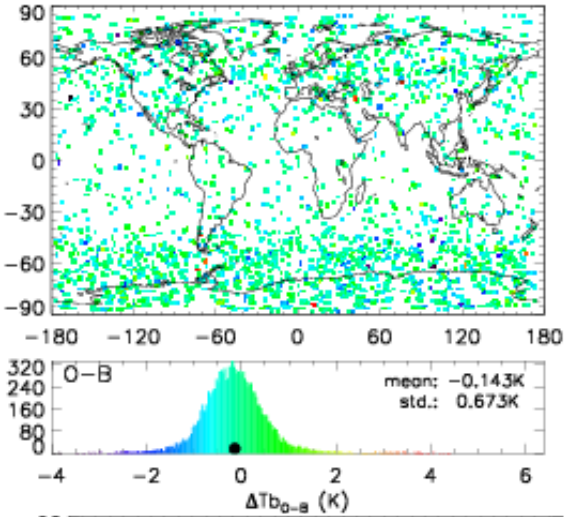
ATMS Bias at Channel 7

Observations

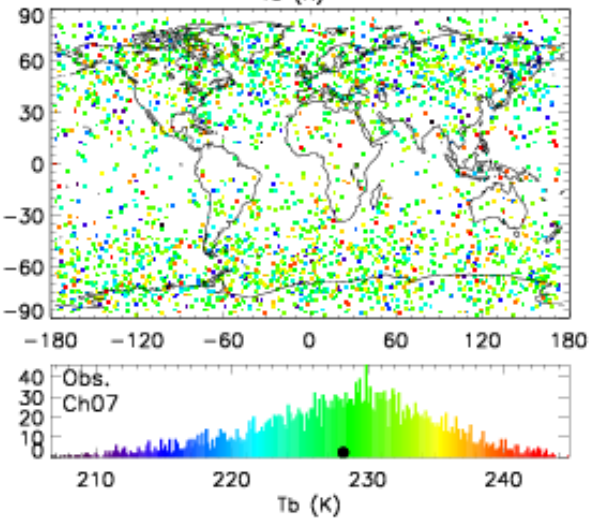
Observation - Simulation (GPS)

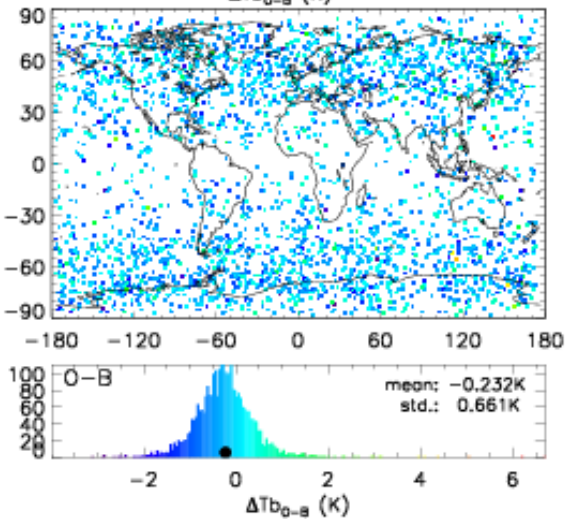
Ch07





Dec.10~31
2011



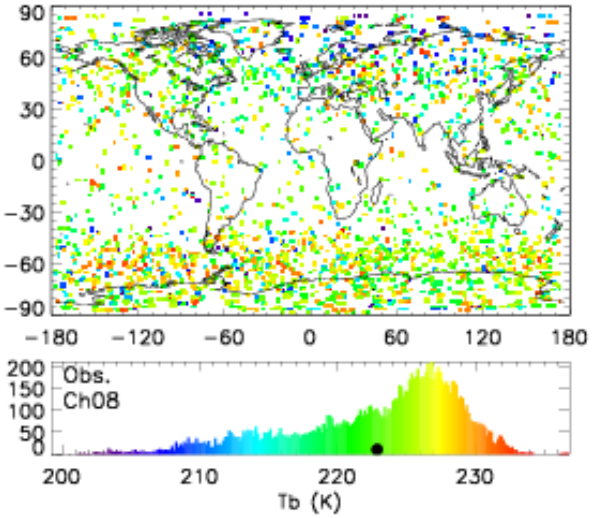


Jan. 2012

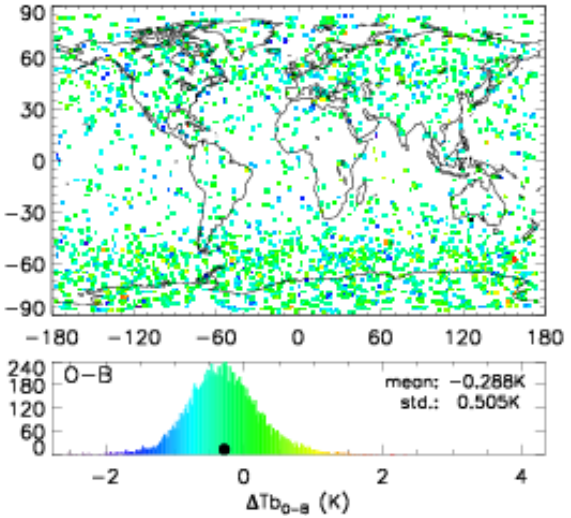
ATMS Bias at Channel 8

Ch08

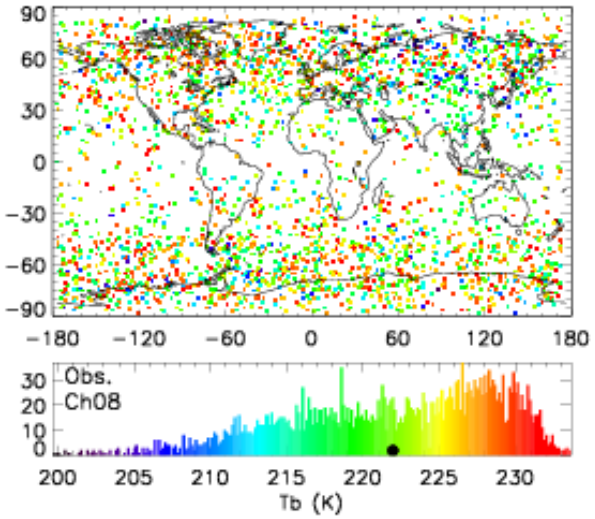
Observations

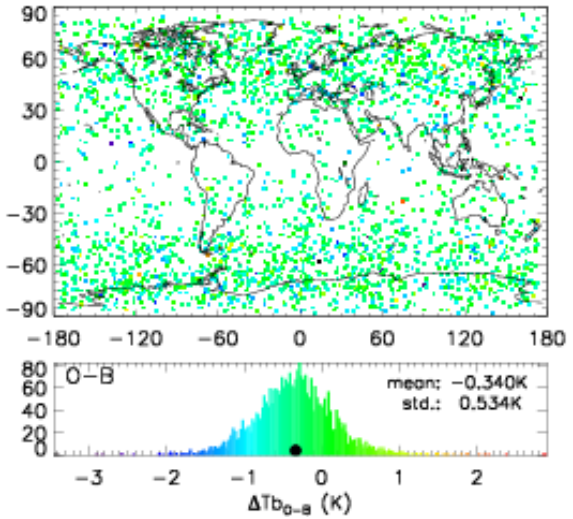


Observation - Simulation (GPS)



Dec.10~31 2011



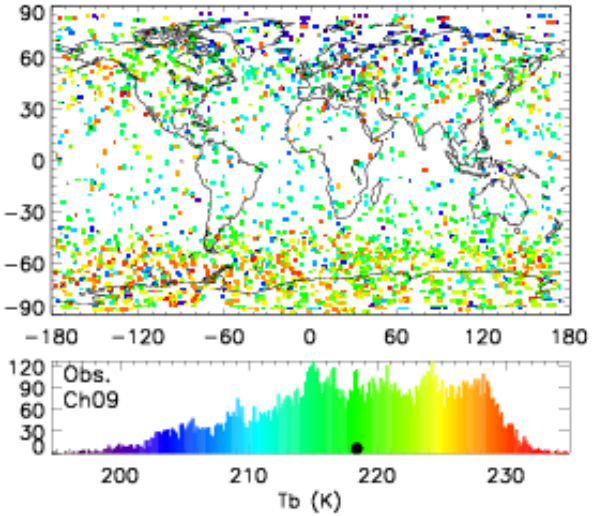


Jan. 2012

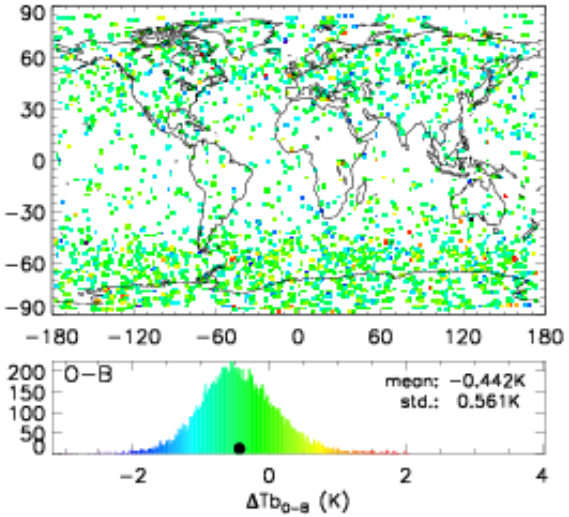
ATMS Bias at Channel 9

Ch09

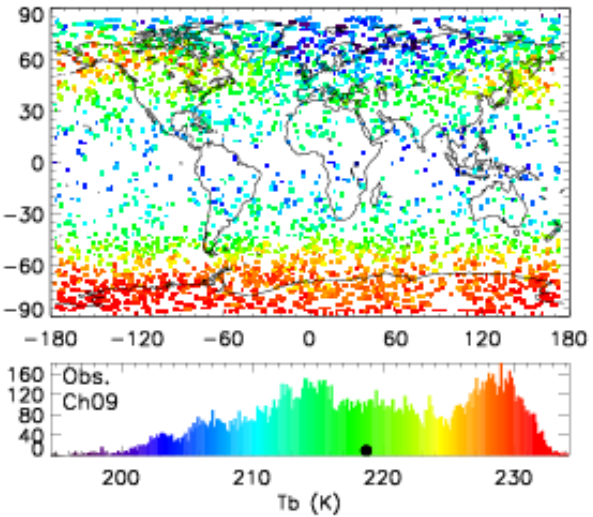
Observations

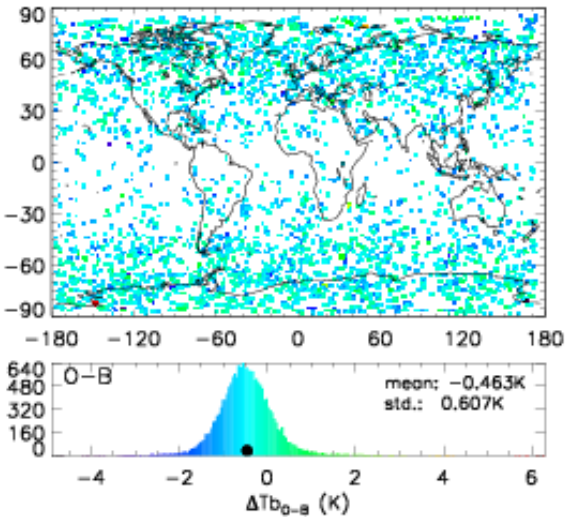


Observation - Simulation (GPS)



Dec.10~31 2011

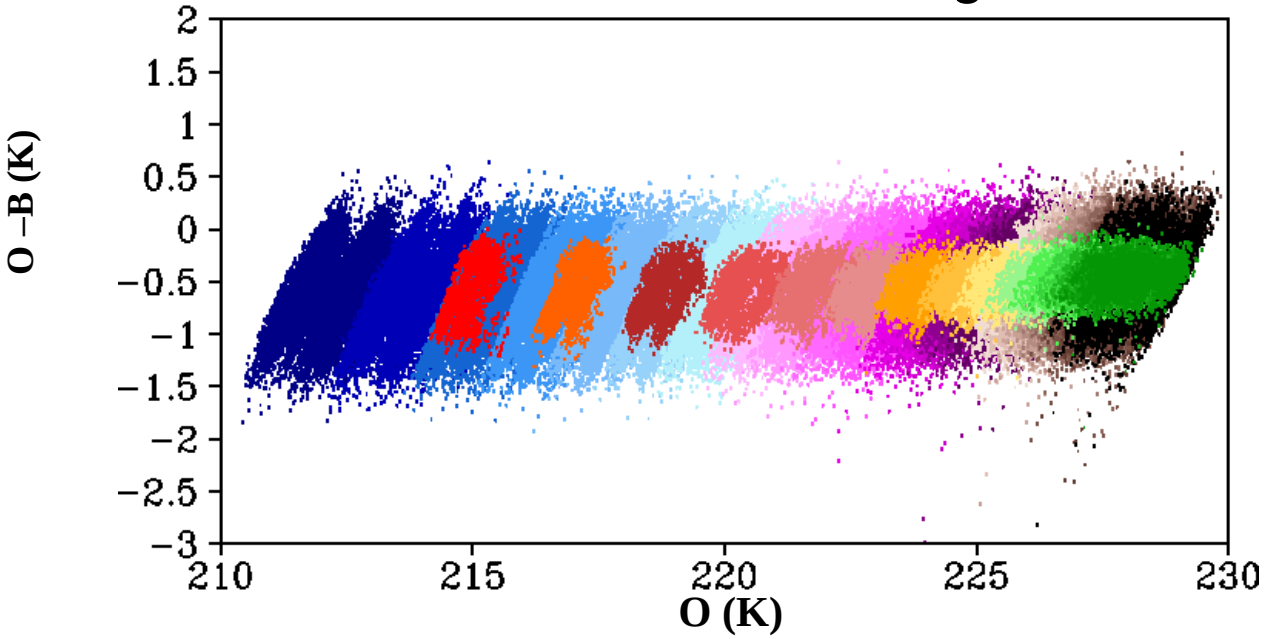




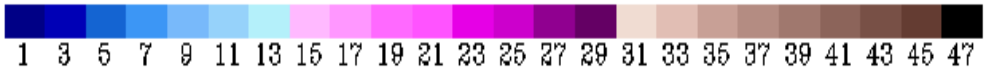
Jan. 2012

Impacts of ATMS Spatial Re-sampling on NWP O-B

Channel 8 O-B using GFS



Resampled ATMS has the same bias at all brightness temperatures but much smaller spread (high innovation)

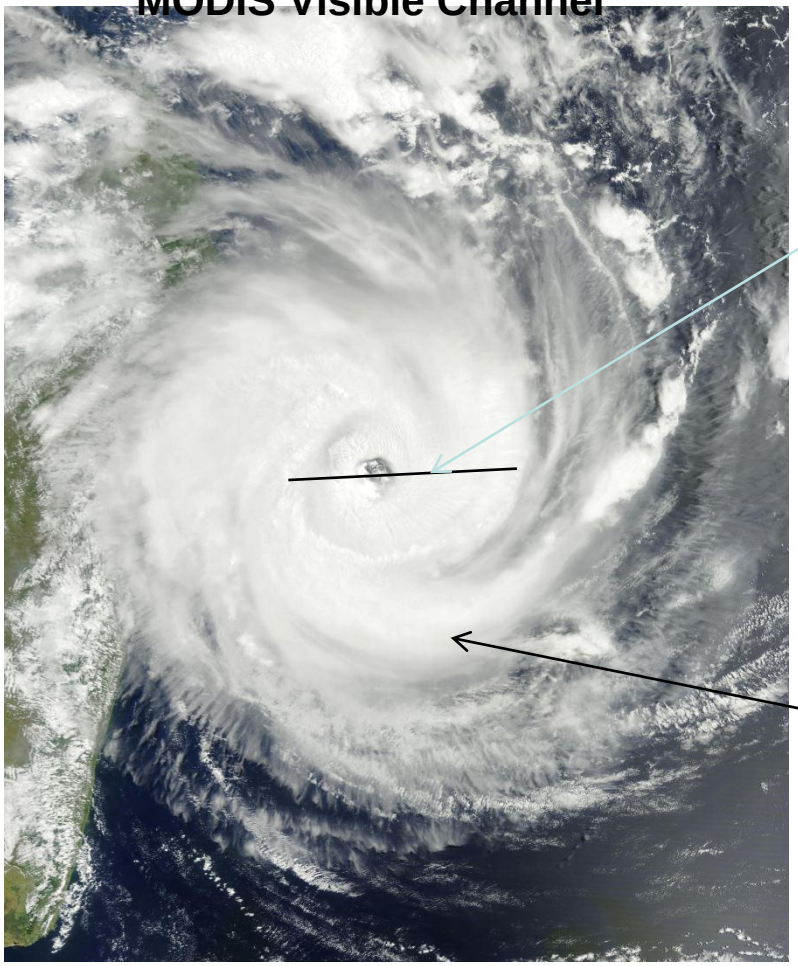


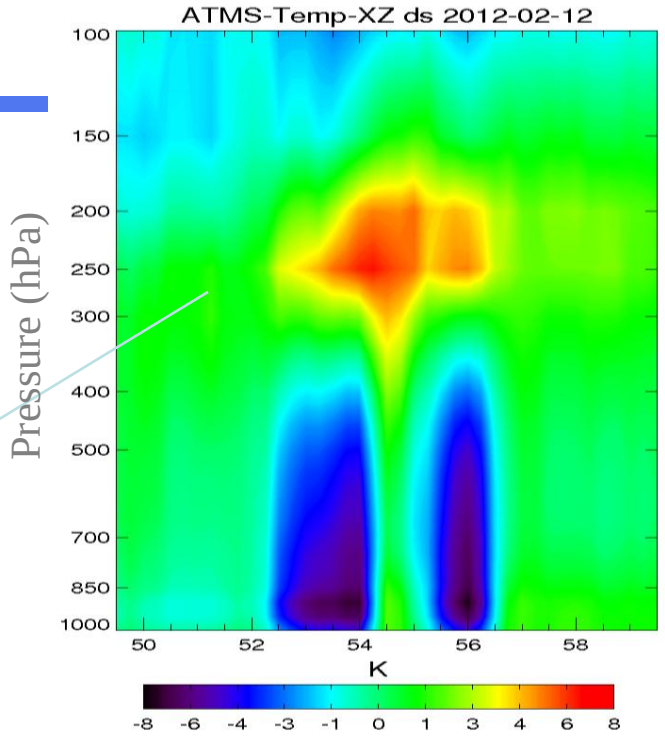
Original ATMS

Remap ATMS

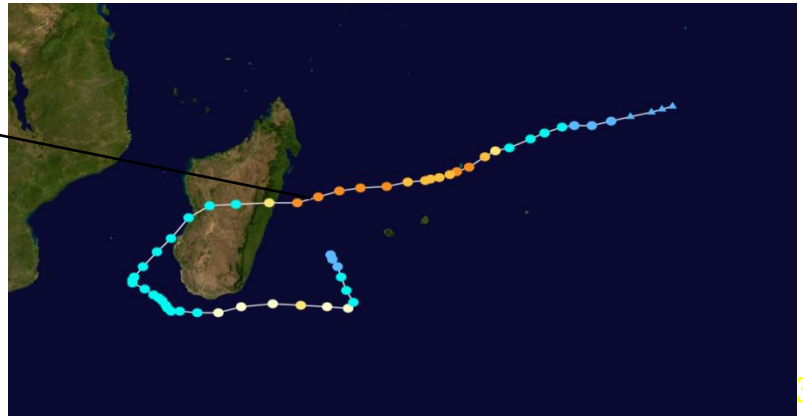
ATMS Monitors Well the Development of Tropical Cyclone Giovanna

Giovanna at Feb 13 2012 0630Z
MODIS Visible Channel

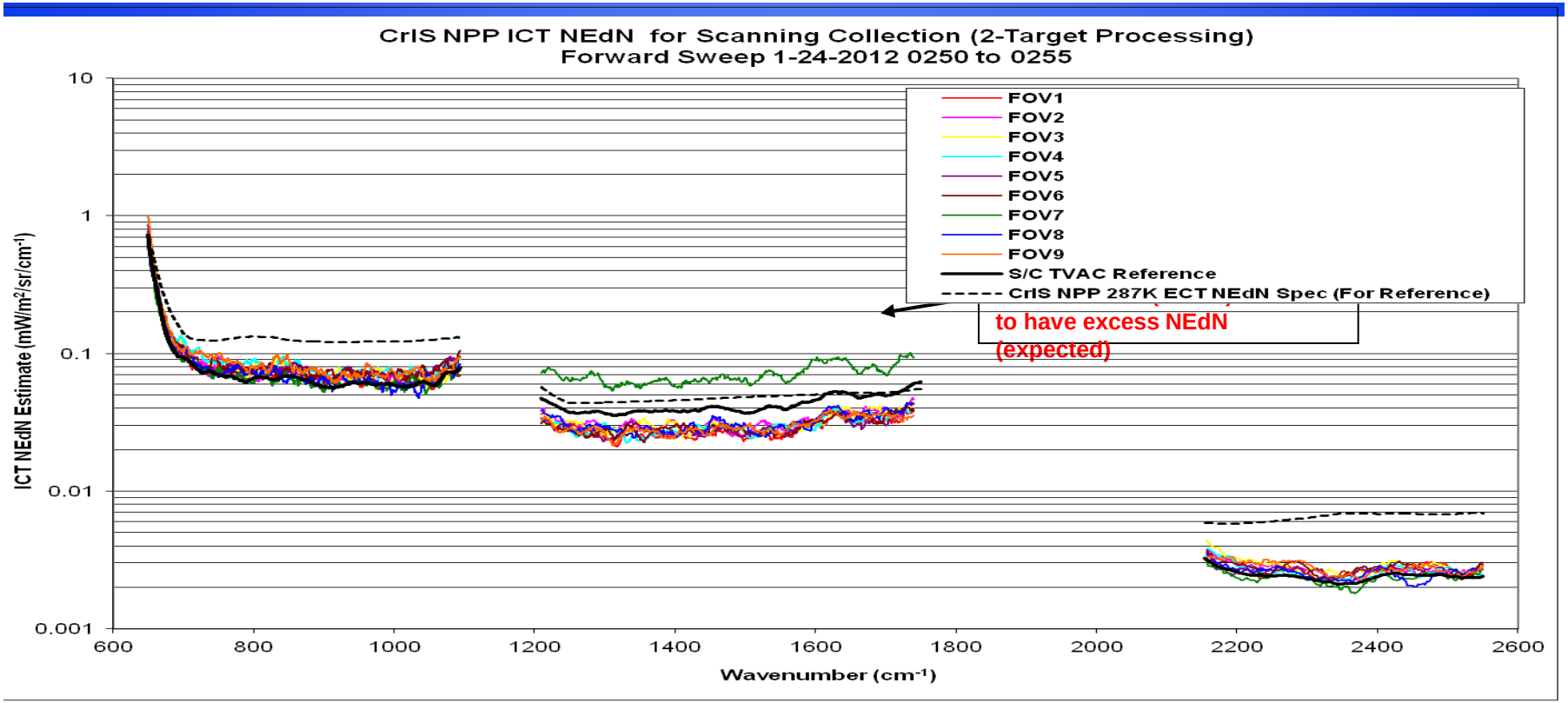




A warm core of 8K ore more at 250 hPa from ATMS indicated a category 4 to 5 hurricane intensity



CrIS Noise Equivalent Differential Radiance (NEdN)

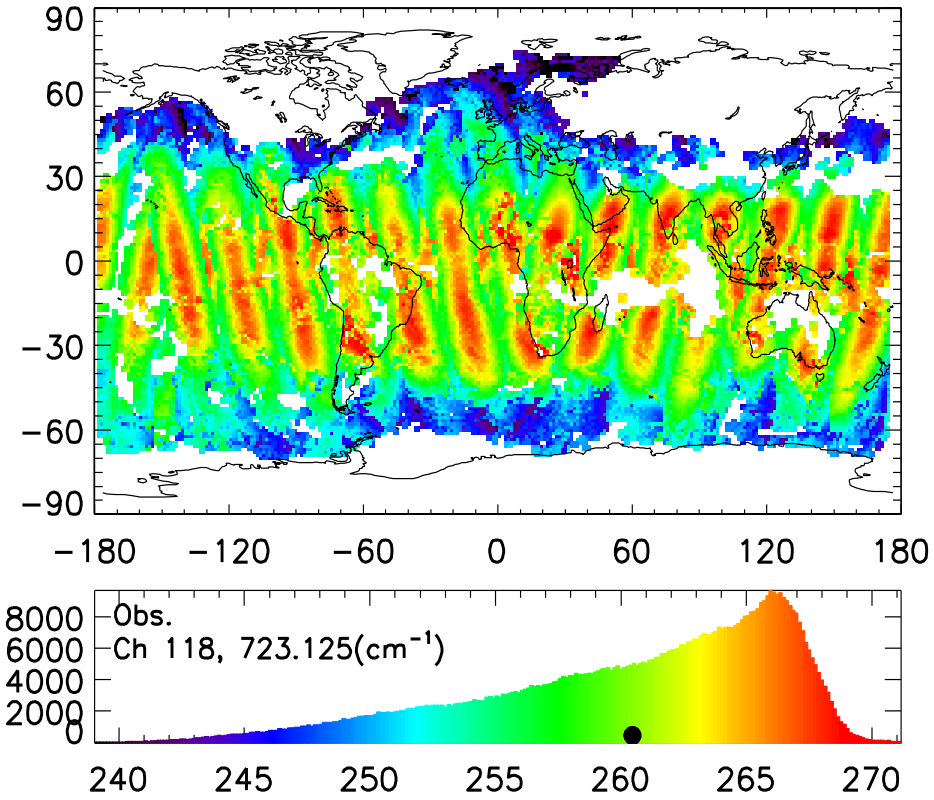


NEdN On-Orbit Data is Consistent with Ground Test Data (Black Lines); Much Better Than Spec Limits (Dashed Lines)……No Ice Contamination Signatures

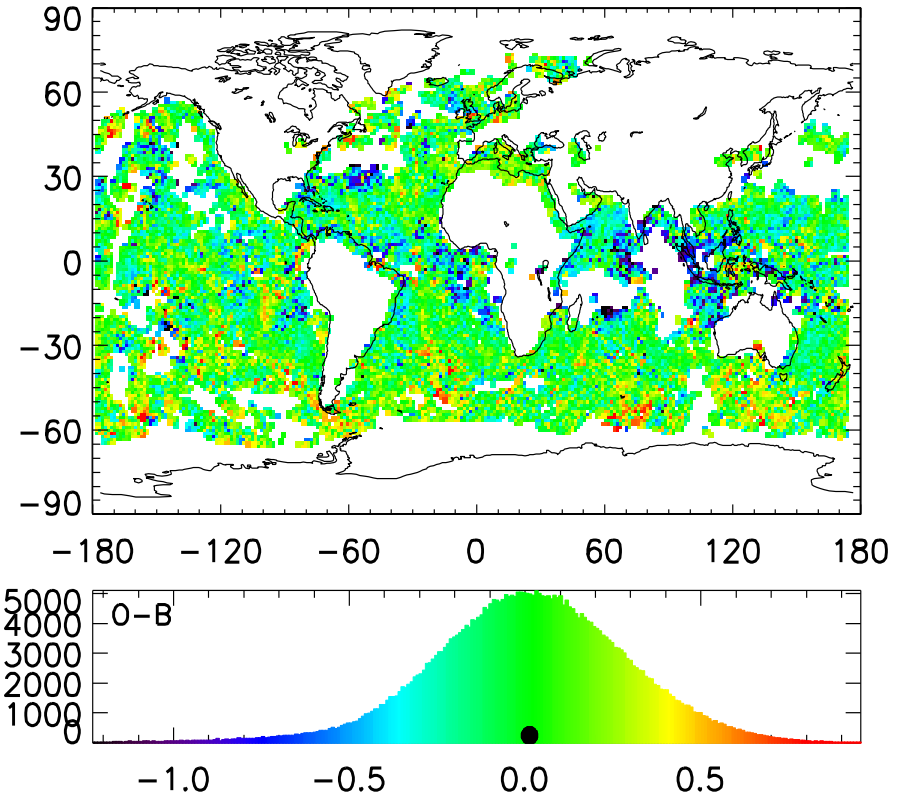
Slide curtsey of Joe Predina, ITT EXELIS

CrIS O-B at Channel 118 (723.125 cm-1)

Observation

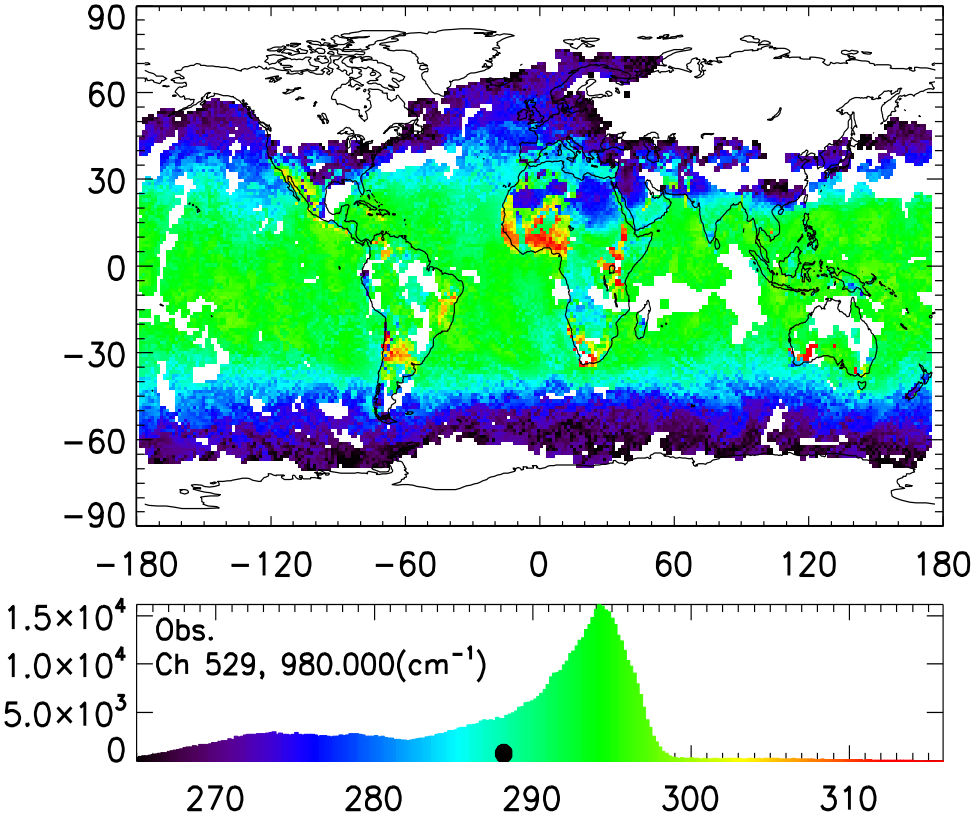


Observation (O) – Simulation (B)

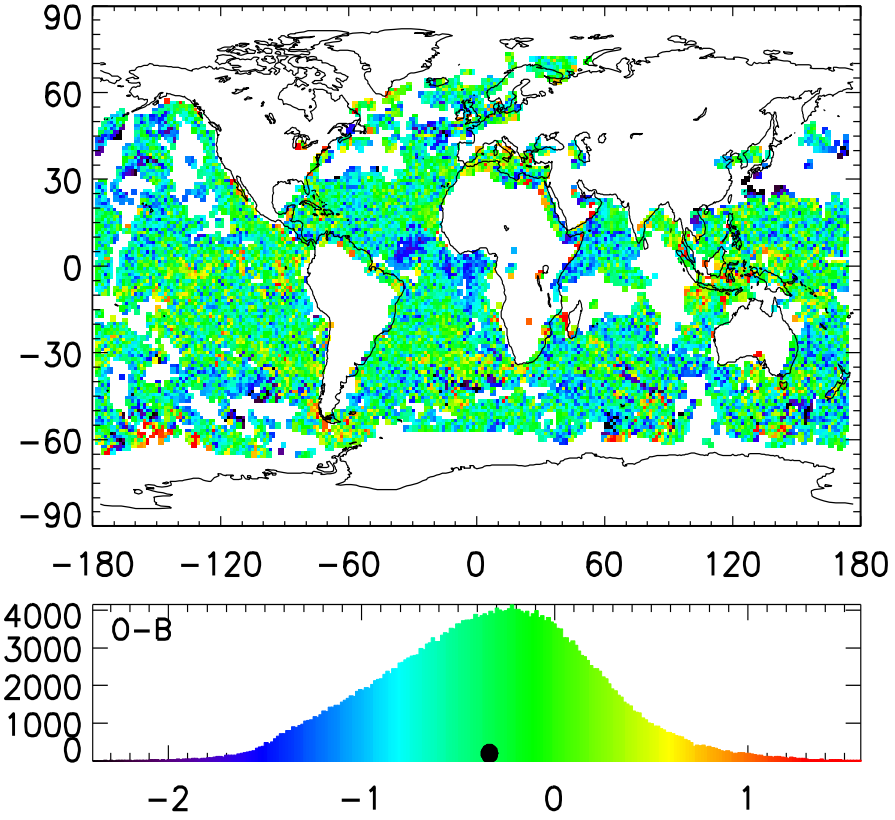


CrIS O-B at Channel 529 (980 cm-1)

Observation

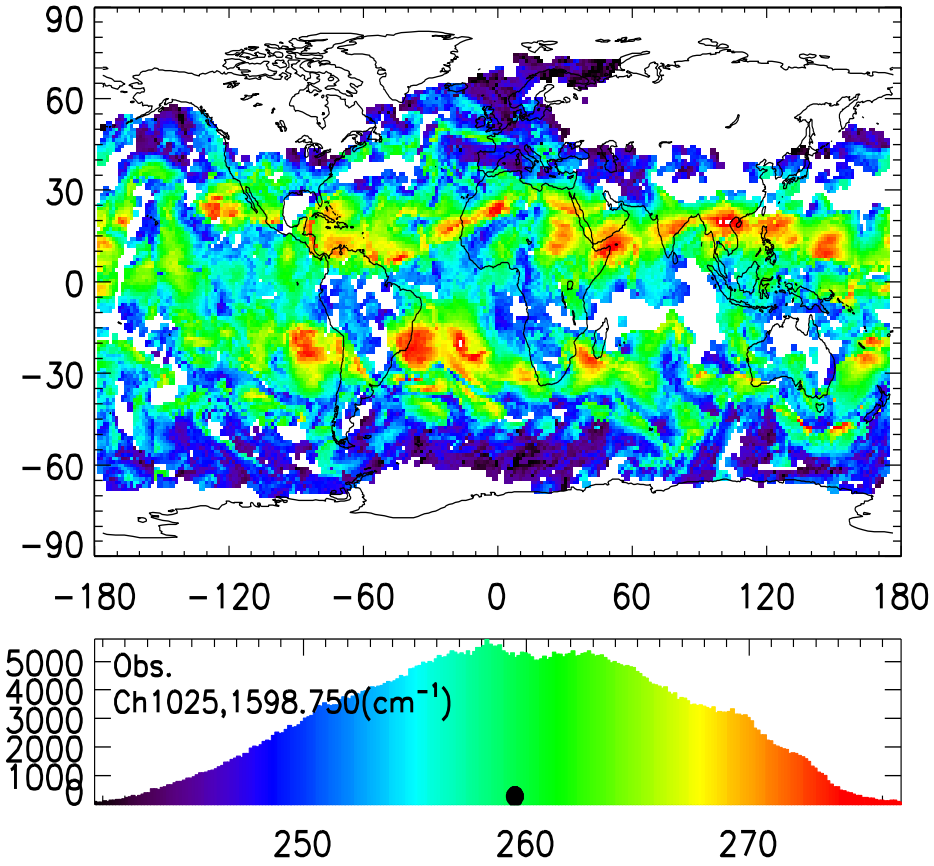


Observation (O) – Simulation (B)

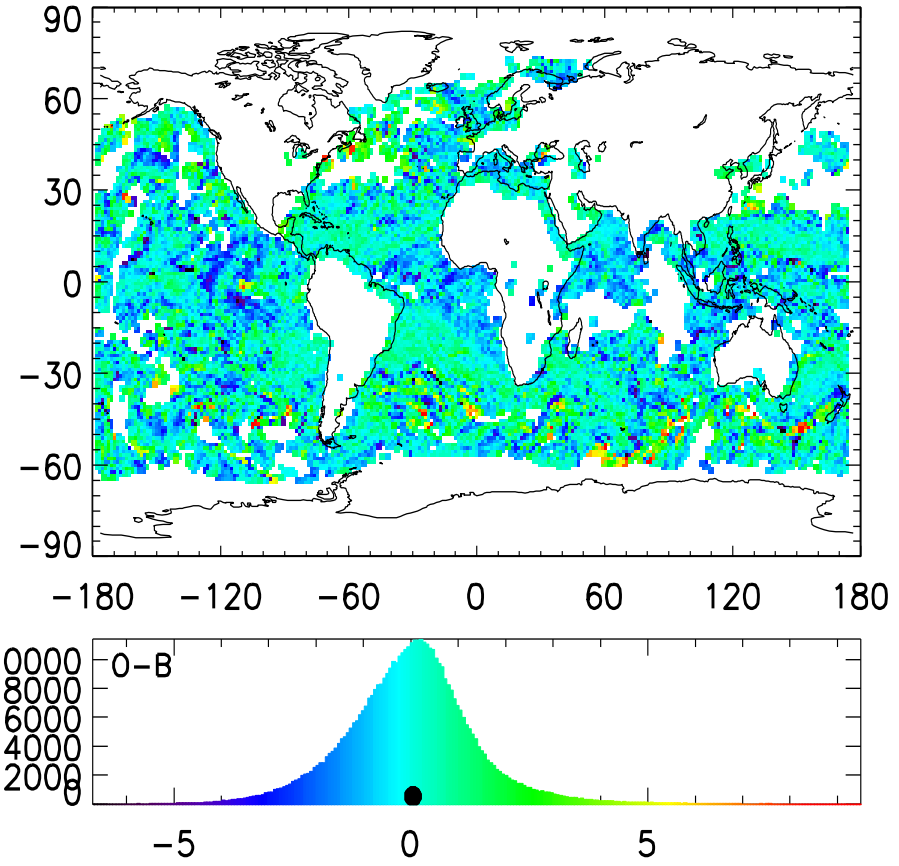


CrIS O-B at Channel 1025 (1598.75 cm-1)

Observation



Observation (O) – Simulation (B)



Summary & Conclusions

• AMSU-A and GOES imager data contribute most significantly to improved QPFs near Gulf of Mexico

• Assimilation of GOES imager radiances produced added values to any single type of satellite data

• Assimilation of all types of satellite data in the GSI system did not produce a better forecast than any experiment assimilated a single type of satellite data

The problems with the all-satellite-data arise from inclusions of MHS and GSN data

• Elimination of MHS data over areas where GOES imager detects clouds significantly improved the MHS data impacts, suggesting an improved MHS QC is required

• NPP ATMS and CrIS radiances are well calibrated now and will provide a high quality of data for our researcg to further improve geo data impacts

Publications

Zou, X., Z. Qin and F. Weng (2011): Improved coastal precipitation forecasts with direct assimilation of GOES 11/12 imager radiances, *Mon. Wea. Rev.*, 222, 111-111.

Zou, X., Z. Qin and F. Weng (2012): Evaluating added benefits of assimilating GOES imager radiance data in GFS for coastal QPFs *Mon. Wea. Rev.*, (revised)

Qin, Z., X. Zou and F. Weng (2012): Development of a new quality control algorithm for effective MHS data assimilation in GSI, *Mon. Wea. Rev.*, (to be submitted) .

Weng, F., X. Zou, X. Wang, S. Yang and M. Goldberg (2012), Introduction to new ATMS characteristics for tropical cyclone research and applications. *J. Geophys. Res.*, (to be submitted)